



## Sustainable supply chains in the world of industry 4.0

Herbert-Hansen, Zaza Nadja Lee; Pietro, Erika Di

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# Proceedings of the 22<sup>nd</sup> International Symposium on Logistics (ISL 2017)

## **Data Driven Supply Chains**

Ljubljana, Slovenia

9 – 12th July 2017



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## INTRODUCTION

Once again we are delighted to welcome our friends and colleagues, both old and new, to the 22nd International Symposium on Logistics in the charming location of Ljubljana, Slovenia. The beautiful, yet historic city of Ljubljana is Slovenia's capital and largest city is one of Europe's greenest and most liveable capitals. Car traffic is restricted in the centre, leaving the leafy banks of the emerald-green Ljubljanica River, which flows through the city's heart, free for pedestrians and cyclists. Slovenia's master of early-modern, minimalist design, Jože Plečnik, graced Ljubljana with beautiful buildings and accoutrements; attractive cities are often described as 'jewel boxes', but here the name really fits. The city has over 50,000 students as well as wonderful museums, hotels and restaurants. Considering the location and the global challenges and current trends, we have chosen the theme of "Data Driven Supply Chains" for this year event. We hope this gives participants the opportunity to share and exchange their ideas and views on their current and proposed research work. It also presents an opportunity to engage in various discussions and debates during the course of the event and see how our models, concepts and findings are pushing the frontiers of knowledge in the area of logistics and supply chain. Equally, it is important to explore how our cumulative know-how in our discipline can be successfully applied to develop the next generation of experts through our teaching and curriculum development as well as helping the practitioner community to enhance the competitiveness of industry.

For us as event organisers, it is especially gratifying to see that this year's symposium will once again be a truly international event having attracted submissions from across the globe. This, together with the healthy balance of participants who have contributed regularly to the symposium over the years, combined with many first time participants who inject new ideas and points of view into the community, promises to make the event an enjoyable and valuable experience.

A particular strength of the ISL community is the enthusiasm of the participants. As the number of parallel sessions during the programme is kept low, many participants value the personal touch and community feeling that this engenders. Having the opportunity to receive personal feedback during the formal sessions, coupled with discussions and debates at the many informal setting that the symposium offers, invariably results in a memorable experience.

As in previous years, all abstracts and/or full papers were reviewed by two or more academic experts from the field of Logistics and Supply Chain Management. This book of proceedings containing the accepted papers, has been organised according the following categories:

- General Supply Chain Management
- Supply Chain Services
- Customer-Supplier Relationships
- Urban Logistics and Humanitarian Logistics
- Applications of ICT in Supply Chains
- Inventory and Warehouse Management
- Complexity, Risk and Uncertainty
- Transport and Distribution
- Sustainability in Logistics and Supply Chains
- Cold Chain Management
- Supply Chain Performance Assessment

To date ISL has been held in Europe, Africa, Australasia and Asia (please see full list below). Following last year's successful event in an attractive location of Kaohsiung, Taiwan, we are very much looking forward to meeting you all at this year's symposium in Ljubljana, Slovenia.

Last but not least we would like to take this opportunity to express our sincere thanks to all the presenters, delegates, reviewers, Advisory Committee members, organising team, invited guest speakers, sponsors, partner journals and local organising team for their excellent organisation and contributions. Finally, our special thanks go to Mrs Maeve Rhode and Norbert Baricz for their support throughout the event and Mengfeng Gong for her help in preparing the proceedings.

Professor Kulwant S Pawar, Dr Andrew Potter and Professor Andrej Lisec – July 2017

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# **Session 1: General Supply Chain Management**

## STRUCTURE OF THE LEAN LITERATURE: JOURNAL QUALITY ANALYSIS

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### Abstract

#### Purpose of this paper:

Over the last three decades, the topic of 'Lean' (Womack and Jones, 1996) has become firmly established within the field of logistics and supply chain research. This conference paper builds upon the work presented at ISL'16 (Francis *et al.*, 2016), and represents the second stage of a programme of bibliographic research into the topic of Lean. The first stage of the programme was a Citation Analysis (CA). This identified the 241 most influential publications on the topic of lean, as measured by citation; the dominant academic approach for providing insight into the significance of individual publications (Peng and Zhou, 2006; Aguinis *et al.*, 2014). Borrowing terminology from Pilkington and Meredith's (2009) bibliometric analysis of the operations management field, our conference paper will provide insight into the intellectual structure of the set of (most influential) lean publications that were identified during the previous stage of the study. The objective of our study is to analyse and evaluate the relative quality of the journal papers that comprise 78% of that dataset. Such evaluation is established with reference to the *Academic Journal Guide* produced by the *Association of Business Schools* (ABS, 2015).

#### Design/methodology/approach:

Due to the atheoretical nature claimed for the Lean literature, it was decided to use Google Scholar (GS) as the source database; the most extensive bibliometric search and indexing source. Ten key word (KW) search phrases that were common synonyms for the Lean paradigm were established. After first checking for relevance to the Lean paradigm, the full reference details of the top 50 most highly cited publications that contained exact phrase matches in the title for each of these ten KWs were copied into a file. These were in turn merged and duplicate references removed to form a Merged Data Set (MDS) of the 241 most highly cited publications on Lean.

Once established, the MDS was descriptively analysed in various ways; including by host publication type. For those publications identified as a Journal Paper, the following categorisation was appended to each following consultation with the ABS (2015) guide:

- ABS (2015) Listed?
- ABS (2015) Journal Ranking.
- ABS (2015) Journal Subject Area.

**Findings:**

The 241 publications in the MDS represent an aggregated total of 98,829 citations. This underlines the degree of influence of these Lean publications, with the lowest ranked entry accruing over 300 citations. The MDS was comprised of only two types of publication: Books (and book chapters) and Journal Papers. Within the MDS, 189 (78%) of the publications were Journal Papers. These represented an aggregated citation total of 58,365 (59% of the MDS total). Of these Journal Papers, 147 (61%) were drawn from ABS (2015) listed journal titles. These represented 51,206 (88%) of the total MDS Journal Paper citation count.

Further detailed analysis on host journal quality ranking and subject area will be provided in the completed conference paper.

**Value:**

By analysing its intellectual structure generally, it is possible to better understand the characteristics and reasons for the undeniable influence exerted by the Lean literature on both academics and practitioners. In addition, the specific ABS (2015) analysis documented in this paper provides valuable commentary on the utility of the ABS (2015) journal guide, as well as potentially assisting logistics and supply chain academics in journal targeting decisions for their future publications on the topic of Lean.

**Research limitations/implications (if applicable):**

There are two main limitations. The first of these lies in the construct of the KW phrases used in the search strategy. Clearly, the nature of the KW phrases used in the queries will determine the publications that are subsequently identified to form the MDS, and hence the subsequent analysis. To minimise this limitation we used ten KW synonyms for 'Lean'. These were established after the systematic review of all existing bibliographic analyses of the lean literature (ie the KWs used in all previous studies). In addition, a 'sanity check' was made of the MDS to ensure that it contained no major omissions of Lean publications considered seminal by all of the authors.

The second limitation is the use of the ABS (2015) journal guide as the point of reference for categorising the 'quality' of the host journal titles. We recognise that this is a potentially contentious issue, especially among UK academics.

**1. INTRODUCTION**

Over the last three decades, the topic of 'Lean' (Womack and Jones, 1996) has become firmly established within the field of logistics and supply chain research. This conference paper builds upon the work presented at ISL'16 (Francis *et al.*, 2016), and represents the start of the second stage of a programme of bibliographic research into the topic of Lean. The first stage of the programme was a Citation Analysis (CA). This identified a dataset of the 241 most influential publications on the topic of lean, as measured by citation; the dominant academic approach for providing insight into the significance of individual publications (Peng and Zhou, 2006; Aguinis *et al.*, 2014). This dataset is presented as a sample of the wider population of lean literature.

The second stage of the programme will provide a detailed evaluation of the structure of the lean literature, so that its characteristics and influence among academics and practitioners might be better understood. This paper represents the first of a number of deliverables from that second phase. Using both citation and publication counts as measures of influence, its specific objective is to

analyse the journal papers that comprise over 78% of the dataset, and evaluate the relative quality of these. Such evaluation is established with reference to the *Academic Journal Quality Guide* produced by the *Association of Business Schools* (ABS, 2015).

## 2. METHODOLOGY

The first stage of the research design had three process steps. The first of these was to select the bibliographic database that was to host the source population of publications for subsequent descriptive analysis. Any such database needed to provide searchable citation statistics on an individual, un-aggregated publication level. In addition, the substantial personal experience of the authors with the lean literature suggested that many of its most highly cited publications were likely to be books rather than journal papers. It was therefore important to select a database that encompassed the widest range of publication types. Google Scholar (GS) was subsequently selected as it is the most extensive academic indexing source. GS draws material from publishers, professional societies and university repositories in a broad range of academic disciplines. In addition to journal papers, conference papers, theses, dissertations, abstracts it also includes books, pre-prints and technical reports. GS therefore encompasses material associated with practitioners as well as academics; thereby partly addressing the concern raised by Aguinis et al. (2014) regarding the single (academic) stakeholder focus of the standard CA approach.

Having established the source database, the second step of the research process was to design the query search strategy to be used to identify relevant publications. Taken in conjunction with lay meanings of the word 'lean', the polymorphic nature of the lean concept highlighted by Samuel et al. (2015) poses particular challenges to constructing query search phrases that identify the population set of publications that are specific and most pertinent to the lean paradigm. The choice of search phrases will clearly influence the subsequent publications considered for analysis. However, researchers need to make informed choices in such circumstances to establish practical limits (Seuring and Gold, 2012). Based upon a consensus between the authors of this paper, ten lean synonym search phrases were subsequently agreed upon. These were: '*lean manufacturing*', '*lean production*', '*lean thinking*', '*lean management*', '*value stream*', '*Toyota*', '*world class manufacturing*', '*Japanese manufacturing*', '*just in time*' and '*kaizen*'. All employed an exact phrase match in the publication title, no date restrictions, and were for all publication types (excluding patents, case law and citations).

The third research process step was to implement this search strategy. The detailed results of each query were presented in highest to lowest number of citations per publication sequence, with some queries resulting in thousands of hits. The top 25 most relevant publications for each query were then identified, and the full reference details copied into an Excel worksheet. This entailed reading the abstracts of each publication in sequence to ensure it was relevant to the lean paradigm, until the 25 most highly cited relevant publications were identified. The net result was 250 individual publication reference details contained within ten worksheets. These were then merged and duplicate publication entries removed. This formed a merged dataset (MDS) of 241 unique publication reference details; representing an aggregated total of 98,829 citations. For each reference in the MDS, individual field details included the rank position (according to-); total citations; author/s; year of publication; publication title and relevant publication outlet data fields.



The second stage of the research design involved enhancing the MDS with the additional data fields necessary to enable the planned evaluation of the lean literature. The deliverable reported upon in this paper required journal/ quality coding. It was decided to use the 2015 edition of the Association of Business Schools' Academic Journal Quality Guide (ABS) as the vehicle to support this exercise. ABS is a guide to the relative quality of journals in which business and management academics publish their research; derived from peer review, editorial and expert judgements (ABS, 2015, p.5). ABS has become particularly prominent in the UK over recent years, and has a number of advocates (Hussain, 2011; Morris et al., 2011). However, it should be noted that both the objectivity of the guide itself and the managerial uses to which it has been applied have been criticised by some academics (see Willmott, 2011; Hoepner and Unerman, 2012).

With this research limitation in mind, a publication-type code was added for each of the 241 MDS publications to signify whether it was a book, book chapter, conference paper, journal paper or report. In addition, a unique journal code was produced for every individual journal title represented within the dataset (eg 'IJPR'). For all publications identified as a journal paper, the appropriate journal code was appended at this point to signify its source journal title. A master list of the MDS journal titles was then built. With reference to the ABS (2015) document, three fields were subsequently added to each journal title entry to facilitate sorting and evaluation: is the title listed ('yes' or 'no'), what is the journal's quality rating ('1'-'4\*'), and to what subject area does the title belong?

### 3. DISCUSSION

The MDS composition by publication type is summarised in Table 1. As with all of the tables contained within this section, details are provided of the influence of each table entry, where such influence is expressed in terms of both total number of publications and total number of citations within the MDS. This table highlights that 97.5% of the MDS publications are books and journal papers. Indeed, the (189) academic journal papers that form the focus for the remainder of this article comprise 78.4% of the total MDS publications; a surprisingly high proportion for a topic that is considered atheoretical by many commentators. The other important finding contained within Table 1 is that the 19.1% of the MDS comprised of books represent 40.3% of its total aggregated citations. Reference to the final column of the table reveals that the average number of citations per book is over two and a half times that per journal paper.

**Table 1. Influence by publication type (all publications)**

Publication Type	Publications		Citations		Avg./ Pub
	#	%	#	%	
Book	46	19.1	39,785	40.3	865
Book Chapter	2	0.8	214	0.2	107
Conference Paper	2	0.8	176	0.2	88
Journal Paper	189	78.4	58,365	59.1	309
Report	2	0.8	289	0.3	145
<b>TOTAL</b>	<b>241</b>		<b>98,829</b>		

For the remainder of this article we focus on evaluating only the characteristics of the journal papers within the above. Table 2 summarises the ABS (2015) listing details of the journal papers contained in the dataset. Nearly 78% of these MDS papers are found in listed journals, and these account for nearly 88% of the total

journal paper citations. In fact, the average number of citations per publication of listed journal papers is twice that of the non-listed figure.

**Table 2. Journal paper breakdown: ABS listed?**

ABS Listed?	Publications		Citations		Avg./ Pub
	#	%	#	%	
NO	42	22.2	7,159	12.3	170
YES	147	77.8	51,206	87.7	348
<b>TOTAL</b>	<b>189</b>		<b>58,365</b>		

We now turn our attention to the 147 journal papers that are found in ABS (2015) listed journals; starting with an evaluation of the relative academic quality of the journal titles that these publications are found in. Table 3 details the official ABS (2015) definition for each of its five quality ratings. ABS uses these to classify and rank 1,401 business and management journal titles within 22 subject areas.

**Table 3. Definition of ABS journal quality ratings**

<b>ABS Rating</b>	<b>Meaning</b>
4*	Journals of Distinction. Within the business and management field including economics, there are a small number of grade 4 journals that are recognised world-wide as exemplars of excellence. Their high status is acknowledged by their inclusion in a number of well-regarded international journal quality lists. The Guide normally rates a journal 4* if they are rated in the highest category by at least three out of the five non-university based listings – Financial Times 45, Dallas List, VHB, Australian Deans' List, CNRS. In addition, journals from core social sciences disciplines that do not appear in those listings may also be rated 4* on the grounds that they are clearly of the finest quality and of undisputed relevance to business and management. In the Guide of 2015, this applies to three journals from the fields of sociology and psychology.
4	All journals rated 4, whether included in the Journal of Distinction category or not, publish the most original and best-executed research. As top journals in their field, these journals typically have high submission and low acceptance rates. Papers are heavily refereed. Top journals generally have the highest citation impact factors within their field.
3	3 rated journals publish original and well executed research papers and are highly regarded. These journals typically have good submission rates and are very selective in what they publish. Papers are heavily refereed. Highly regarded journals generally have good to excellent journal metrics relative to others in their field, although at present not all journals in this category carry a citation impact factor.
2	Journals in this category publish original research of an acceptable standard. A well regarded journal in its field, papers are fully refereed according to accepted standards and conventions. Citation impact factors are somewhat more modest in certain cases. Many excellent practitioner-oriented articles are published in 2-rated journals.
1	These journals, in general, publish research of a recognised, but more modest standard in their field. Papers are in many instances refereed relatively lightly according to accepted conventions. Few journals in this category carry a citation impact factor.

Source: ABS (2015, p.7).

Using the above journal quality ratings, Table 4 details the MDS journal papers by each quality rating level. In terms of publication count, this table reveals a distinct skew towards higher rated journals, with over 75% of all listed papers being found in journals rated '3-4\*'. Indeed, the largest proportion can be found in '3' rated journals (33.3%), whilst the two smallest categories are '2' and '1' rated respectively. In terms of citations, the skew is even more pronounced with the '3-4\*' rated journals yielding nearly 92% of the aggregated citations. In fact, there is an extremely high correlation ( $r=0.957$ ) between journal quality rating and the average number of citations per publication for the MDS papers categorised for that rating.

**Table 4. Journal paper influence by ABS quality rating**

Quality Rating	Publications		Citations		Avg./ Pub
	#	%	#	%	
4*	27	18.4	16,760	32.7	621
4	36	24.5	13,706	26.8	381
3	49	33.3	16,414	32.1	335
2	16	10.9	2,015	3.9	126
1	19	12.9	2,311	4.5	122
<b>TOTAL</b>	<b>147</b>		<b>51,206</b>		<b>348</b>

The 147 ABS listed journal papers contained within the MDS are drawn from 70 different journal titles. Importantly, these titles are dispersed across 19 of the 22 ABS subject areas. Of course, this distribution is far from even among either the journal titles or ABS subject areas. Table 5 details the latter. In terms of publication count, the top three categories account for over 72% of the listed papers. *Operations & Technology Management* is unsurprisingly the largest category; accounting for 51% of the papers. Perhaps more surprisingly, this is followed by *General Management, Ethics & Social Responsibility* which accounts for an additional 13.6% of the listed papers. *Economics, Econometrics & Statistics* accounts for a further 7.5%.

**Table 5. Journal paper influence by ABS subject area**

Subject Area	Publications		Citations		Avg./ Pub
	#	%	#	%	
<i>Accounting</i>	4	2.7	492	1.0	123
<i>Business History &amp; Economic History</i>	1	0.7	124	0.2	124
<i>Economics, Econometrics &amp; Statistics</i>	11	7.5	4,439	8.7	404
<i>Entrepreneurship &amp; Small Business Management</i>	1	0.7	346	0.7	346
<i>Finance</i>	1	0.7	785	1.5	785
<i>General Management, Ethics &amp; Social Responsibility</i>	20	13.6	7,750	15.1	388
<i>HRM &amp; Employment Studies</i>	5	3.4	967	1.9	193
<i>Information Management</i>	2	1.4	229	0.4	115
<i>Innovation</i>	1	0.7	96	0.2	96
<i>International Business &amp; Area Studies</i>	2	1.4	162	0.3	81
<i>Management Development &amp; Education</i>	1	0.7	54	0.1	54
<i>Marketing</i>	2	1.4	906	1.8	453
<i>Operations &amp; Technology Management</i>	75	51.0	23,487	45.9	313
<i>Operations Research &amp; Management Science</i>	7	4.8	2,806	5.5	401
<i>Organisation Studies</i>	2	1.4	1,369	2.7	685
<i>Psychology (Organisational)</i>	3	2.0	877	1.7	292
<i>Sector Studies</i>	2	1.4	187	0.4	94
<i>Social Sciences</i>	3	2.0	1,378	2.7	459
<i>Strategy</i>	4	2.7	4,752	9.3	1,188
<b>TOTAL</b>	<b>147</b>		<b>51,206</b>		<b>348</b>

If we turn to citation analysis, then the top three categories again account for over 70%, although the actual subject areas are slightly different. *Operations & Technology Management* is again the leading category, with 45.9% of total ABS

listed citations. *General Management, Ethics and Social Responsibility* is again second, with 15.1%. However, the third highest subject area category by citation is *Strategy*, yielding 9.3% of the citations.

#### 4. CONCLUSIONS

This paper represents the first deliverable of a programme of research that aims to detail the wider structure of the lean literature. The discussion in the previous section yields three important conclusions. First, the high prevalence of journal papers (78%+) in the MDS throws into question the claim that lean is an atheoretical topic. Second, a very significant skew in terms of publication and citation count was noted towards the highest ABS journal quality ratings. This was reinforced by a very high correlation between quality rating level and the average number of citations per publication for that category. This suggests that ABS journal quality rating is a reliable proxy for degree of citation; certainly for the lean literature. If such ratings are indeed an indication of the underlying academic quality of the journal outlet, then this further reinforces the first conclusion. Lastly, the discussion revealed that the MDS journal publications were drawn from 19 of the 22 ABS subject areas, underlining the extent of diffusion of the lean paradigm within the business and management literature more widely.

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# PARADOXES IN PACKAGING DEVELOPMENT ORGANISATIONS

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## ABSTRACT

Existing research on how to organise packaging development is scarce and superficial, in particular advantages as well as disadvantages of organisational designs are not well understood. As a means to break new grounds regarding these advantages and disadvantages, the purpose of this paper is to apply a paradox approach to identify, categorise and describe paradoxes inherent in different ways of organising packaging development. By describing and categorising the paradoxes, this explorative and conceptual paper advances knowledge about organisation of packaging development. Awareness of these paradoxes can be considered as a first step towards successful management of them.

**Keywords:** Logistics performance, organisation, packaging, paradox, supply chain

## INTRODUCTION

In logistics research it is well known that the design of packaging systems greatly affects logistics performance in terms of effectiveness and efficiency of distribution, materials handling and level of damaged products in supply chains (Klevås, 2005). To enhance appropriate logistics performance regarding these aspects there is a need for new, innovative packages, ensuring future logistics performance in the supply chain. As such, innovations and development of packaging systems has been identified as a crucial aspect for supply chain performance (Pålsson and Hellström, 2016).

Despite the importance of packaging development, existing research on how to organise this development is scarce. Although scholars acknowledge this as an important research area (e.g. Bramklev, 2009; Klevås, 2005), few in-depth studies on the characteristics of possible organisational designs for packaging development exist. Beyond identification of organisational characteristics there is a need for a structured approach regarding pros and cons with these design options, which is lacking in current research.

There are several alternatives for how to describe a packaging development organisation. Two generic dimensions, anchored in contemporary organisational theory on development processes, are (1) the degree of centralisation (Klevås, 2005) and (2) the degree of project organisation (compared to pure functional organisation) (Ulrich & Eppinger, 2008). Different positions within these two dimensions provide different organisational advantages and disadvantages that need to be handled and exploited. It is evident that the strengths and weaknesses of different designs varies, and that the organisational design selected has to balance goals and strategies.

As a means to break new grounds regarding the advantages and disadvantages of different organisational designs of packaging development, this paper applies paradox theory that stems from contemporary organisational research. By focusing on the paradoxes inherent in an organisation, typically defined as “contradictory yet interrelated elements that exist simultaneously and persist over time” (Smith and Lewis, 2011, pp. 382), different types of tensions such as those between centralisation and decentralisation, control and flexibility, and global and local are continuously balanced (Sandberg, 2017). More specifically, the research in this paper applies a theoretical framework of four paradox classes (learning, belonging, performing, and organising) as a means to develop more structured knowledge upon pros and cons with different organisational designs of packaging development. To distinguish different design options from each other, the two dimensions of degree of centralisation and degree of project organisation are discussed. Based on this argumentation, the purpose of this paper is to apply a paradox approach to the organisation of packaging development to identify, categorise and describe paradoxes inherent in different ways of organising packaging development.

## METHOD

This explorative paper applies a new theoretical lens in packaging logistics research. Based on Smith and Lewis’ (2011) framework on classes of paradoxes (i.e. belonging, performing, organising, and learning), two organisational dimensions (degree of centralisation and degree of project organisation) are analysed in terms of paradoxes inherent, see Figure 1 below. It is a conceptual analysis, exemplified with paradoxes found in previous research projects on packaging logistics as well as existing literature. Our aim is not to provide an exhaustive list of possible paradoxes, but rather to provide examples and demonstrate the presence of different paradoxes in different organisational designs.

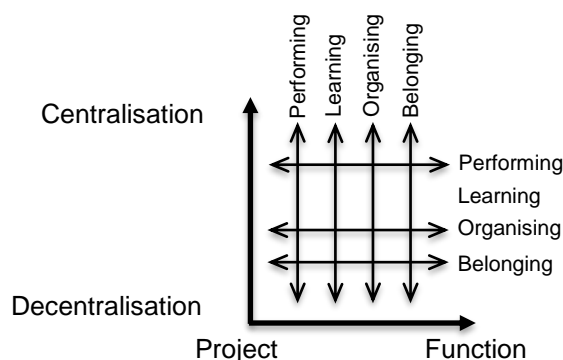


Figure 1. An overview of the analysed dimensions and the paradox classes applied

## ON PARADOX THEORY

Recent years’ theoretical development within the organisational field of research calls for a renewed understanding of how to manage contradictions and tensions within an organisation (Dameron and Torset, 2014). Whereas some tensions are possible to avoid or solve (Smith and Lewis, 2011), some of them, here labelled paradoxes, are not. Consequently, the core message of a paradox theory is that to manage organisations (or supply chains) effectively, these paradoxes must continuously be coped with (Sandberg, 2017). Creating awareness of these paradoxes and their impact on company performance is considered a major tool for organisational development (Graetz and Smith, 2009). If tackled correctly, the paradoxes could be seen as an important driving force for innovation and development (Sandberg, 2017; Graetz and Smith, 2009; Lewis, 2000).

In their seminal paper on paradox theory, Smith and Lewis (2011) developed a framework of different types of organisational paradoxes. These four types are in this research applied as a framework to structure our understanding of pros and cons with organisational design of packaging development. The four types are (Smith and Lewis, 2011, pp. 383):

1. Learning (knowledge): Efforts to adjust, renew, change, and innovate foster tensions between building upon and destroying the past to create the future.
2. Belonging (identity/interpersonal relationships): Identity fosters tensions between the individual and the collective and between competing values, roles, and memberships.
3. Organising (processes): Structuring and leading foster collaboration and competition, empowerment and direction, and control and flexibility.
4. Performing (goals): Plurality fosters multiple and competing goal as stakeholders seek divergent organisational success.

### ON DIMENSIONS OF A PACKAGING DEVELOPMENT ORGANISATION

Although there are numerous ways of how to describe a packaging development organisation, this paper limits the discussion to two major contingency variables: the degree of centralisation and degree of project organisation. By combining these two dimensions a short overview of some key characteristics are provided in Figure 2.

	Centralisation	Decentralisation
Functional organisation	High packaging competence High packaging authority Central links to logistics Long lead time for product and packaging development	Close connection to product development No clear links to logistics Weak packaging authority in the company as a whole, but locally strong Loss of packaging competence (but stronger than in a decentralised project organisation)
Project organisation	Close connection to product development Control and coordination of packaging activities Central links to logistics High packaging authority Risk of a bureaucratic organisation	Close connection to product development Insufficient communication, coordination and control No clear links to logistics Weak packaging authority Loss of packaging competence

Figure 2. Characteristics of different packaging development organisations (based on Klevås, 2005)

### PARADOXES IN PACKAGING DEVELOPMENT ORGANISATIONS

Our analysis is based on applying paradox theory to the organisation of packaging development in two dimensions. First, we present paradoxes related to the degree of centralisation and then related to the degree of project organisation.

#### Dimension 1: Degree of centralisation

##### *Performing*

Two performing paradoxes arise depending on the degree of centralisation of the packaging development organisation. The first is the ability of a company to have a long-term packaging development process with analogous performance focus and at the same time be able to provide customised packaging solutions. The overall economic and environmental performance goals of packaging in terms of, for example, product protection, transport efficiency, ease of handling, and the choice of packaging material are always inherent and trade-offs between various requirements need to be made. In a centralised packaging development organisation these can be managed and overviewed relatively easily. In a decentralised packaging development organisation, it is more challenging to have a common company practice for coordinating and balancing the trade-offs. For instance, one decentralised unit may focus on packaging protection, while another focus more on packaging cost and a third puts more emphasis on the environmental concerns. Thus, in the long term, failure of proper management of divergent performance

goals tends to jeopardise a synchronised overall strategic development process of packaging.

The second performance paradox concerns the distribution of packaging development resources between different product categories, projects and business units. Due to the holistic overview in a centralised packaging development organisation, the management attention and resource distribution can typically be based on well-planned, informed decisions. Resources will be allocated from a company perspective to enhance overall company performance, for instance avoiding sub optimisations due to strong local leaderships. In a fully decentralised development organisation the lack of control and overview may hamper effective and efficient prioritisation among different development projects, products, or similar. Instead responsiveness and rapid change of different performing objectives is here acknowledged and emphasised.

### *Learning*

The learning paradox for packaging development organisations concerns the organisational capabilities of maintaining knowledge, e.g. providing and disseminating formal up-to-date training, and at the same time acknowledge and absorb emergent knowledge in a less formalised manner. For instance, it is essential to have formal, in-company training for how to apply new packaging materials, but it is also necessary to learn about e.g. packaging material innovations in a more informal, emergent manner. The degree of centralisation affects the organisational capability to address the learning paradox. In a centralised organisation, the knowledge and competence are more stable over time as more people and other resources reduces the dependency on certain individuals. In a decentralised organisation, a key resource may have all knowledge, which can be eliminated if that person quits. Thus, it is more challenging to maintain knowledge over time in a decentralised organisation.

A centralised organisation usually have more resources for market scanning making it more likely to get new influences. On the other hand, a decentralised organisation may get more insights from local markets. In addition, the adoption of insights from the market scanning in a centralised organisation may be slow as current practices may be guarded by several individuals. Thus, in a centralised packaging development organisation, the general market scanning capability is greater, but a decentralised organisation offers better opportunities to adopt new practices based on local insights for incremental packaging development.

The degree of centralisation affects the implementation of new packaging knowledge or an identified need for packaging development training. The dissemination of new knowledge and new processes is typically more straightforward and easier to make uniform in a centralised organisation than in a decentralised organisation one.

### *Organising*

An organising paradox that has to be handled by packaging development organisations is that of control vs. flexibility. A highly centralised organisation typically facilitates control of a number of managerial issues, such as total packaging development costs, knowledge development over time, project management and coordination of suppliers. A decentralised organisation is, in contrast, often equipped with higher flexibility towards, for instance, fulfilment of specific customer demands and other entrepreneurial development activities from a "bottom-up perspective".

Competition vs. collaboration is another organising paradox relevant for packaging development organisations. Whereas centralisation may facilitate collaboration and coordination among different business units e.g. in the form of joint learning, use of same product and packaging platforms etc., competition may be facilitated in more decentralised organisation. Competition can favour organisational development. In centralised packaging organisations, a lack of competition may lead to stagnation in packaging knowledge development. In a decentralised packaging organisation, various subunits compete, which

can favour packaging knowledge development. However, a paradox is related to that unsound competition may lead to unwillingness to share knowledge.

### *Belonging*

Belonging considers whether an organisation primarily identifies with itself as an individual or a group. In centralised packaging development organisations the focus is on the whole company, while a decentralised organisation usually identifies itself with the subunit. The belonging paradox becomes essential to manage in more decentralised organisations. With absence of strong, centralised management there is a risk of suboptimisation as each department or business unit may focus on their own packaging development. Such suboptimisation typically have their roots in two causes. First, financial interests may lead to that a department favours and prioritises their own costs before the company's interests. Second, there could be a lack of knowledge and understanding of needs and requirements in other parts of the company.

To sum up, the paradoxes for degree of centralisation is presented in Table 1.

Table 1. Summary of paradoxes for degree of centralisation

<b>Paradox class</b>	<b>Paradox in packaging development</b>	<b>Centralisation</b>	<b>Decentralisation</b>
Performing	Long-term performance focus vs. Customised packaging solutions	Long-term focus embedded in the structure, facilitating analogous performance focus across the entire company	Customised packaging solutions (in terms of e.g. lead times) with different performance focus in different business or product units.
	Well-planned vs. responsive, ad-hoc allocation of packaging development resources	A holistic overview facilitates informed decisions and efficient resource allocation of resources	Responsiveness and rapid change of different performing objectives is acknowledged and emphasised
Learning	Maintaining current knowledge vs. capturing emerging knowledge	Embedded in the structure are e.g. formalised training systems and education programmes	Depends on few individuals, difficult to maintain competence over time – needs management
	Provide and disseminate formal up-to-date training	Supported by the organisational structure, but the application of new knowledge and new practices can be difficult as current practices are guarded	Different organisational units may develop in different directions, needs management for similar training
	Acknowledge and capture emergent knowledge in a less formalised manner	More resources for market scanning, but difficult to adopt practices to local needs	Possibilities to adopt practices to local needs, but more difficult to have resources for general market scanning
Organising	Control vs. flexibility	Lacks flexibility to customise packaging solutions	Lacks control of overall packaging development issues (total costs, knowledge creation etc.)
	Competition vs. collaboration	Risk for stagnation in packaging knowledge development	Competition between subunits favours packaging knowledge development, but unsound competition may lead to unwillingness to share knowledge
Belonging	Company vs. subunit	Focus on aligned packaging development in the company	Risk for suboptimisation when each subunit focuses on their own packaging development

### **Dimension 2: Degree of project organisation**

The second dimension describes the degree of project organisation of packaging development. Both a project organisation and a decentralised organisation are subunits, but the main difference is that a decentralised organisation either can be organised as functional silos (decentralised function organisation) or in as an interdepartmental project organisation (decentralised project organisation). In a similar manner, a project

organisation it is possible to have an interdepartmental project organisation within a centralised organisation. Thus, the degree of project organisation highlights to what extent the organisation supports functional integration. Next, the four paradox classes are analysed for the degree of project organisation.

#### *Performing*

In a functional organisation, packaging development follows product development in a linear process, whereas in a project organisation packaging and product development usually are parallel processes. Thus, the total development time for product and packaging is faster in the project organisation. Due to the linear process of the functional organisation, all packaging requirements are specified before packaging development, while in the project organisation the requirements are managed in an iterative process throughout packaging development, as the stakeholders (e.g. marketing and logistics) are involved in the process. Hereby, in packaging development organisations with a high degree of project organisation, conflicting performance goals on packaging from logistics, marketing and product development typically becomes more visible and a need for instant management where the goals are balanced against each other. Thus, it could be argued that the main performing paradox for functional organisation is between sufficient up-to-date information of stakeholder requirements on packaging and well-balanced packaging decisions (can be done as information is available from the beginning). For project organisations, on the other hand, the main performing paradox is between the well-informed packaging requirements and the ability to balance conflicting performance goals.

#### *Learning*

Overall, the learning paradox could be considered as a struggle between deep and broad knowledge. Organisations with low or high degree of project organisation focus on the different extremes. This constitutes a learning paradox; function-oriented organisations tend to create and maintain in-depth expertise in different areas, e.g. in packaging materials and packaging technology. Thus, the main learning paradox is between building on current knowledge and replacing current knowledge with radical ideas. In comparison, a project-oriented organisation enables contextual understanding in which the project is working. Such an organisation is better in adjusting packaging solutions to a context, but has less depth in the solutions. The learning paradox is between depth and broadness in packaging knowledge.

#### *Organising*

Similar to the organising paradox in the dimension of degree of centralisation, packaging development organisations face organising paradoxes for control vs. flexibility, collaboration vs. competition, and empowerment vs. direction.

In a functional organisation, there is a risk for latent competition, meaning that the packaging development organisation may not include or consider packaging requirements from all potential stakeholders. For instance, logistics may realise that the packaging solution did not consider requirements on stackability or volume efficiency. The paradox is between an efficient and timely packaging development process and collaboration with stakeholders for inclusion of packaging requirements. Furthermore, a functional organisation focuses on standardised packaging solutions and control rather than flexibility. Thus, the paradox is between maintaining control and being flexible in packaging development. Finally, this way of organising supports packaging authority meaning that empowerment is strong for packaging development. Thus, the paradox is for the company to keep the packaging development in a direction that is beneficial for the company.

In a project organisation, both collaboration and competition are considered in the packaging development process as it considers various stakeholder perspectives. These organisations also focuses on flexibility in terms of customer-oriented packaging solutions. They usually focus on supply chain performance and customer satisfaction. However, there is a paradox related to control, as the flexibility focus can lead to inefficiency and

uncontrolled development of the organisation over time. Regarding collaboration and competition, the organising paradox is that collaboration *between* business functions may be facilitated in a project organisation, whereas collaboration *within* the packaging function may be less intense and well developed.

### *Belonging*

The focus and belonging of a functional organisation is packaging and packaging development. For a project organisation, the focus and belonging is the packed product. By focusing on packaging, the functional organisation tends to focus on the main packaging functions, such as protection, unitisation and containment. Thus, the belonging paradox is between maintaining this packaging competence and widening the considerations for indirect effects of packaging in the supply chain. By instead focusing on the packed product, the project organisation have a more holistic approach where the performance of both packaging and products in the supply chain are considered. However, this leads to a belonging paradox for project organisations, as this focus tends to erode packaging authority and limit the role of the package in the project (in comparison to the main product) and that overall supply chain performance becomes more important than the packaging competence (Klevås, 2005).

Table 2. Summary of paradoxes for degree of project organisation

Paradox class	Paradox in packaging development	Function	Project
Performing	Up-to-date requirements vs. well-balanced packaging decisions	Enable well-balanced packaging decisions, but challenging to obtain up-to-date requirements	Enable up-to-date requirements, but a challenge is to manage conflicting performance goals for packaging
Learning	Depth vs. breadth in packaging knowledge	Create and maintain in-depth packaging expertise, but a trade-off between building on current knowledge and replacing current knowledge with radical ideas	Enable contextual understanding for packaging solutions, but has less packaging knowledge depth in the organisation
Organising	Control vs. flexibility	Focuses on standardised packaging solutions and control, but lacks flexibility in packaging development	Focus on flexibility can lead to inefficiency and uncontrolled development of the organisation over time
	Competition vs. collaboration	Enable an efficient and timely packaging development process, but minor stakeholder collaboration for inclusion of packaging requirements	Focus on collaboration <i>between</i> business functions, whereas collaboration <i>within</i> the packaging function may be less intense and well developed
	Empowerment vs. direction	Support packaging authority (strong empowerment), but challenging to keep a strong packaging function in a direction that is determined by the company	Focus on project results, but challenging to a risk to loose packaging knowledge
Belonging	Packaging vs. packed product	Support strong packaging competence, but challenging to widening the considerations for indirect effects of packaging in the supply chain	Focus on the performance of the packed product, but can erode packaging authority and limit the role of the package in the project

## CONCLUSIONS

The organisation of packaging development for effective and efficient logistics has received sparse research attention. Advancing the knowledge of paradoxes inherent in different types of packaging development organisations provide understanding of challenges and tensions that need to be managed for improved effectiveness and efficiency of the packaging design, which in turn is essential for the overall logistics performance in the supply chain.

The explorative analysis of this paper has resulted in an overview of possible paradoxes inherent in the product development organisation. From the findings, we conclude that there is not one, single preferable organisational way of organising packaging development. Rather, different organisational designs result in different paradoxes that must be managed. By describing and categorising the paradoxes, this paper advances the knowledge about organisation of packaging development. Awareness of these paradoxes can be considered as a first step towards successful management.

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# **ASSESSMENT OF SERVICE QUALITY IN SUPPLY OF PHARMACEUTICAL PRODUCTS**

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## **ABSTRACT**

Supply chain management and procurement policies can strongly influence the quality of service provided by companies, therefore its ability to compete in the market. Ten years after deregulation of the pharmaceutical market in Portugal, the industry faces strong challenges. Organized purchasing groups emerged to gain bargaining power towards suppliers. Nonetheless there are traditional players (pharmacies) who remain independent. The purpose of this paper is to assess and compare the perceived quality of the service provided by the traditional distributors with the one from the economic groups, and identify which factors need to be more developed by these groups to improve its service. Twenty pharmacies were interviewed (ten belonging to a specific economic group and ten independent ones). Findings show that the main criteria for supplier selection are the commercial conditions. Although the access to more favourable purchasing prices is the leading reason for pharmacies joining the economic group, lack of fulfilment of the overall commercial advantages announced by the economic groups (such as service consistency and price, when compared to the monthly fee payed to the group) lead some pharmacies to remain independent. Pharmacies manager's management skills were identified as an influencing factor when choosing to be part of the economic group.

Keywords: supply chain management; B2B; service quality; pharmaceutical industry; multiple case study comparison

## **INTRODUCTION**

Portuguese pharmacies are facing a significant increase in competition as the market is no longer as regulated as before. Ten years ago the market became deregulated and many new players (drugstores) entered the market making available all products the traditional pharmacies offered under protection rules. Only the prescribed products remain regulated and available only at the traditional pharmacies.

The drugstores complemented their value proposal by adding complimentary services, such as beauty and nutrition services, among others, representing strong competition to the well-established pharmaceutical market. These new players pressured selling prices down and margins no longer support low rotation inventories or urgent deliveries (that sometimes were available up to 5 times a day) at small volume pharmacies.

One way the pharmaceutical industry found to fight this competitive battle and gain bargaining power towards its suppliers was to aggregate pharmacies in economic groups. These groups allow purchasing products at lower prices due to more bargaining power and aim for high quality in service delivery. At the same time some of these groups also provide management support for those who end up managing the pharmacies but have no management background.

The span of services available at the pharmacies is an important issue for the customers, as well as product availability and attentive care (Silva, 2015). These are some of the issues that influence end customers when deciding where to purchase. By

providing a service that matches retailer's expectations, suppliers can contribute to their development of competitive advantage (Mentzer et al., 2008).

Every pharmaceutical product is potentially available at any pharmacy so besides complimentary services what leads a customer to a specific pharmacy instead of another? Customer service is a strong driver and product availability is at its centre. At the same time investment in inventory is a major concern for the pharmacies as variety is wide and demand uncertainty high. Assuring immediate product availability is a major challenge for pharmacies and overcoming the lead-time gap (Christopher, 2016) is a permanent management issue. Purchasing costs are a major concern as well as on time deliveries, which are issues that pharmacies consider when deciding to join these economic groups or to keep purchasing from the traditional distributors. Under this context, the purpose of this paper is to perceive if there are differences in terms of the supply services provided by the economic groups to its joining pharmacies and the one provided by the traditional distributors/wholesalers, and identify if there are factors that these groups need to improve to make a better service available to the pharmacies. Therefore this research has two main objectives. The first one is to assess and compare the perceived quality of the service provided by the traditional supply chain agreements and the one made available by the economic groups. The second is to identify specific ways in which the economic groups can improve their service. Assessment will be based on the perspective of the customers of the economic groups, i.e., the pharmacies compared to perception of service received by pharmacies that maintain the traditional supply system.

In order to achieve its goal this research grounds its literature review on supply chain management and service quality. Two groups of 10 pharmacies each are compared, one belonging to a specific economic group e the other constituted out of independent pharmacies. Interviews were conducted with the managers of these pharmacies. Content analysis was used for the treatment and analysis of interviews.

## **LITERATURE REVIEW**

It is customer service that more and more sets the difference between the offerings from different players in the same industry (Christopher, 2016). Product availability is one of the most relevant issues in customer service as, although slowly, markets are becoming less sensitive to product brand. This can easily lead to lost sales for the supplier but not exactly to the point of sales as substitute products might be available. Mentzer et al. (2008) posit that by supplying good logistics service companies can add value to the value proposition for the customer and therefore support its customer to sustain competitive advantage in their own market. According to the same authors, this competitive advantage can be achieved with product availability, on time delivery and error free orders. Being able to compete in the market is therefore a consequence of the level of customer value provided, which is heavily influenced by the suppliers' service quality.

Supplier selection if a source of competitive advantage as the player is only as strong as the supply chain it is part of. Strategic procurement can set the competitive scenario of a company when compared with others in the same industry (Simchi-Levi et al., 2008). Searching for the best supply is a dynamic process that impacts the quality of the service the companies provide to their own customers. Being able to develop bargaining power and reduce supplier dependency is a way to reduce procurement costs (Kraljic, 1983).

Procurement plays a major role in creating supply chain resilience (Pereira et al., 2014). In markets where product availability plays a key role in customer service, being able to assure the best suppliers is of paramount relevance. In parallel, being able to supply competitive and resilient service influence buyers to consider those suppliers during their sourcing exercises. Service consistency and short lead times are relevant procurement issues as the retail customer, specifically in the pharmacy's market, aims a very short order cycle (Christopher, 2016).

Based on the conceptual framework, the research question pursued in this research is:

- *In the retail pharmaceutical market, which issues are enhancing or preventing the retailers from joining economic groups and what are the issues these groups should focus on to enhance their service quality to become more attractive for pharmacies' sourcing strategies?*

## **METHODOLOGY AND METHOD**

Research focusses com a single economic group. Pharmacies that are part of this group are compared with a group of similar dimension of independent pharmacies.

The data collecting tool was interview. There were two frames for the interviews, one for the pharmacies that belong to the economic group and one for the pharmacies that do not. The structure of the interview used for the pharmacies that are independent is composed out of three parts: the first one focussed on the pharmacy, its supply and the satisfaction level with the service provided by the suppliers; the second part aimed at topics concerning the reasons that lead the pharmacy not to join any economic group; lastly, a set of topics concerning the quality of the logistic service provided by the pharmacy to its customers. The structure used for the pharmacies that belong to the economic group was also composed out of three parts: the first one focusses on the reasons for joining the economic group; the second part aimed at the satisfaction level with the logistic service and support received from the economic group; the last part aimed at the logistic service provided by the wholesalers the economic group has agreements with its own customers (the joining pharmacies). Wording was adjusted during the interviews to assure interviewee understanding of the topics.

Twenty pharmacies were selected for this research. Out of the 20 selected pharmacies, 10 are part of the economic group and 10 are independent. In order to add variability of context to the research, pharmacies were selected from different districts of Portugal: 12 from Lisbon, 2 from Setúbal, 2 from Évora and 4 from Portalegre.

Interviews were performed with the owner of the pharmacy (which in some cases is also the technical director). Each interview lasted for about 15 to 30 minutes. There were 18 face to face interviews and two interviews performed over the phone.

Interviews were written down and then key words (or its synonymous) were searched for. Data analysis followed Krippendorff (2013)'s recommendation for content analysis.

## **STRUCTURE OF SUPPLY OF PHARMACEUTICAL PRODUCTS**

Portuguese pharmacies can purchase directly from the laboratories or through wholesalers. The laboratories are the producers of the medicines or of other products. The wholesalers purchase from different producers/brands and then supply the pharmacies with a wider range of products.

Globally, all pharmacies have (more or less formal) agreements with the wholesalers from which they receive products on a daily basis. If the wholesaler does not have the product available or in order to use eventual commercial campaigns the pharmacy can purchase directly from the lab. Nonetheless, some pharmacies chose to purchase only from the wholesalers.

The wholesalers' service level depends on the commercial conditions agreed with the pharmacy (service, volume, selling price, number of daily deliveries). Lead times are usually short, of 12 hours up to one day.

The Portuguese pharmaceutical market is strongly regulated and selling prices for medicines are defined by a public institute. These prices are considered low for the labs and wholesalers. These wholesalers can also distribute products to other markets, less regulated or with higher selling prices and it is not unusual that stock outs occur in the Portuguese market because the products were send to more profitable markets. Pharmacies that are part of the researched economic group have access to a purchasing office for all purchases and services. For confidentiality reasons this group is not identified, and will from this point forward be called Group X. Using this Group X the pharmacies have access to lower purchasing prices, which were previously negotiated between the group and the supplier (lab or other supplier). The purchasing price is always an advantage but the service level depends on commercial conditions

negotiated by Group X with the wholesaler. Group X developed commercial agreements with three wholesalers. These wholesalers are not exclusive to Group X. Pharmacies who purchase under the scope of Group X order directly from these wholesalers.

Being born in 2008, by the beginning of May 2017 Group X represented 401 pharmacies. Besides a purchasing centre, Group X provides marketing, financial and human resources management support to their associates, as well as training and in store organization. There are also available specific shared services (such as nutrition) that otherwise the pharmacies would not have enough volume to support. Once part of Group X the pharmacies receive a total makeover of the facilities to assure similar commercial image at all pharmacies in the group. In exchange to the package of services pharmacies pay a monthly fee plus a per cent over their sales.

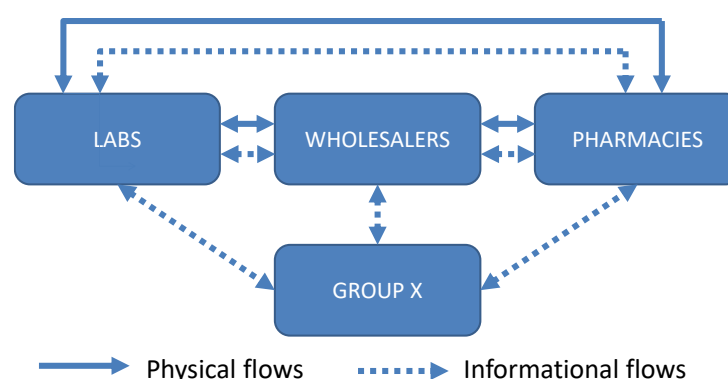


Figure 1 – Physical and informational flows in the supply chain of Group X

Figure 1 shows the physical and the informational flows between the pharmacies that belong to Group X and the players in the supply chain.

There is always a direct and an inverse flow between every entity as returns can occur (due to expiry dates or service issues). Group X works as a purchasing office and does not hold inventory. It also works as an advisory player for management purposes and planner of additional services. The independent pharmacies (that do not belong to Group X) are linked both to the wholesales and the labs as they are not limited to purchase from the wholesalers.

## FINDINGS

When analysing the criteria used by the pharmacies to select their suppliers, findings showed that it is mostly based on commercial conditions offered and product availability. Table 1 shows the main results.

Table 1 – Criteria considered when selecting suppliers

Criteria	Relative per cent (1)
Payment conditions and lead time	100%
Product price	50% (2)
Product availability	50%
Delivery time range and availability during weekends	20%

(1) Out of the 20 interviewed pharmacies

(2) All the pharmacies belonging to Group X (100%)

All the pharmacies belonging to Group X mentioned that they prefer to use the wholesalers with which Group X has agreement. Nonetheless, only 20% of them purchase exclusively from such wholesalers (these pharmacies are owned directly by Group X), when 80% of them state that they preferentially buy from these wholesalers but keep contacts with other wholesalers or labs to complement their offer, to assure supply (not always the wholesalers that have agreements with Group X have product

availability either because Group X missed placing the order or the product is out of stock). Taking advantage of specific campaigns was a criteria mentioned by all the pharmacies that are not part of Group X to purchase specifically from the labs.

In terms of satisfaction with the service provided by their suppliers, Table 2 shows the distribution of answers on a scale from 1 to 1. None of the sampled pharmacies is completely satisfied with the service received from its suppliers but at the same time there are no observations bellow the middle point of the scale, which allows concluding that there are no situations of dissatisfaction. The median satisfaction level is 5, which allows concluding there is room for improvement in terms of the service provided by the pharmacies.

Table 2 – Satisfaction with suppliers' service

Value of scale	1	2	3	4	5	6	7
Per cent	0%	0%	0%	20%	45%	35%	0%

(Legend: 1 – Not satisfied at all; 7 – Completely satisfied)

Table 3 allows comparing the satisfaction of the pharmacies supplied under the scope of Group X and the independent ones. Although the satisfaction level is similar in both groups, there is stronger agreement between the independent pharmacies. Pharmacies supplied under the scope of Group X complain mainly of the lack of ability of the wholesalers to deal with such high level of demand and the stock outs. The wider variability of responses from Group X's pharmacies can also be justified due to the fact that two of these are actually owned by the Group, situation that might prevent those two managers from exposing the real satisfaction level with the wholesalers.

Table 3 – Comparison of satisfaction between groups of pharmacies (supply)

	Global satisfaction	Pharmacies supplied under the scope of Group X	Independent pharmacies
Median	5	5	5
Interquartile interval	1	2	1

Both groups mention lack of product availability as the main reason for their lack of satisfaction. Smaller pharmacies are additionally concerned about this issue as when products are rationed they are usually penalized receiving even less quantity. As for the wholesalers suppling at the prices negotiated by Group X, it is often that they channel their product availability to more profitable customers than to Group X's. Nonetheless, when comparing the two distributions the Mann-Whitney test revealed that the difference is not statistically relevant ( $p=0,392$ ).

Pharmacies in Group X were asked about the reasons for joining the Group. As 2 of them are owned by the Group, only 8 pharmacies were questioned about this topic. Table 4 shows the relative frequency of answers. Pharmacies could identify more than one reason for joining the Group.

Table 4 – Reasons for joining Group X

Reasons for joining	Relative per cent
Access to more favourable prices	63%
Offer of specialized services	50%
Recognition of Group X as having a new strategic model	38%
Need to adapt to the new legal conditions	25%
Differentiation of final service	13%
Improved competences to serve customers	13%

Although financial issues are the main reason for joining Group X, pharmacies also pointed the additional services made available by Group X as a selling issue. Nonetheless, although more affordable prices is the key issue, it has been identified as a selling point Group X cannot fulfil. In fact, this is only a theoretical advantage as it was recognised by these pharmacies that product availability is poor at the selected wholesalers. This is also a reason for these pharmacies to maintain agreements with other wholesalers beyond the selected three.

As for the currently independent pharmacies, Table 5 shows the reasons stated for not joining any economic group.

Table 5 – Reasons for not joining any economic group

Reasons for not joining	Relative per cent
It has not yet been considered	30%
Commercial advantages presented do not compensate	30%
Want to keep their independence	20%
No group has yet showed enough advantages	20%

Findings show that the financial advantages were not enough to capture the attention of these pharmacies. The more modern looking ones do not recognise the need for the support of one of these groups, which leads to conclude that the physical support at the point of sales could be also considered a good value proposition from Group X.

In most cases the technical director of the pharmacy is also the owner, which means that that person has to divide its attention between the technical support to the customers and the management of the business. In one specific case the technical director is fully dedicated to the management of the business and stated that he can achieve as good financial deals as the ones offered by the groups, but that it only happens as a consequence of his time investment in procurement.

When questioned about the quality of the services offered to its own customers, findings showed that the pharmacies recognise that there is scope for improvement. Table 6 shows the results obtained. Although no pharmacy scored below the middle point of the scale, only 10% are fully satisfied with the service provided and the median is at 5 out of a scale of 7 points.

When results from the satisfaction with the service provided (Table 6) are compared with the satisfaction level with the suppliers (Table 2), it can be stated that pharmacies are more pleased with their own service than with the service received from its suppliers.

Table 6 - Satisfaction with its own customer service

Value of scale	1	2	3	4	5	6	7
Per cent	0%	0%	0%	0%	55%	35%	10%

(Legend: 1 – Not satisfied at all; 7 – Completely satisfied)

Comparing the two groups of pharmacies (independent ones vs belonging to Group X), although the satisfaction level with the service provided is higher at pharmacies belonging to Group X than at independent pharmacies, the spread of responses is also higher (Table 7). As 20% of the pharmacies from Group X are owned by the Group, it is possible that is might be influencing the responses.

Table 7 – Comparison of satisfaction between groups of pharmacies (service provided)

	Global satisfaction	Pharmacies belonging to Group X	Independent pharmacies
Median	5	6	5
Interquartile interval	1	1	0

## **DISCUSSION**

Group X assortment is limited, which leads some pharmacies to keep supply agreements with additional suppliers to complement the range of their offer. These parallel agreements also allow taking advantage from campaigns offered by other wholesales or even the labs.

Although lead time was a criterion identified by all pharmacies as a very relevant one to be part of the Group, 8 out of the 10 pharmacies that belong to Group X keep agreements with other suppliers and product availability is one of the reasons. This leads to conclude that although Group X announces a specific lead time, the wholesalers they have agreements with do not fulfil it. The price of the products and product availability were reasons identified by all the pharmacies belonging to Group X for joining the Group. As product availability is not assured at the agreed price, it is possible to conclude that the Group is not providing the main advantages recognised by the pharmacies, forcing these to keep agreements with other wholesalers and endangering the willingness of the pharmacies to keep being part of the Group.

Although the access to more favourable purchasing prices is the leading reason for pharmacies joining Group X, fulfilment of commercial advantages is not recognised latter on (such as service consistency and price, when compared to the monthly fee paid to the group) and lead some pharmacies to keep managing purchasing relations by themselves (being independent from any group).

Pharmacies belonging to Group X show a higher satisfaction level with the quality of the service they provide. In fact, one of the main alterations a pharmacy received when joining the group is the complete alteration of the physical appearance of the space (more modern), customer service training is provided to the store's employees and complimentary services become available for their customers, which influences the satisfaction level they have with the quality of the service they provide. Nonetheless, product availability is a major concern for pharmacies belonging to Group X, which can reduce their satisfaction level with the service provided.

Based on the results obtained, even considering that the sample is not representative of the industry, it is possible to posit that Group X is experiencing some problems in fulfilling the promises it makes to the pharmacies of the Group, especially in terms of product availability at the more favourable prices. Nonetheless, widening the services made available at the pharmacies and the new visual appearance of the spaces are topics well perceived by the pharmacies. As the commercial conditions are a key issue for joining Group X, the Group should adjust its procurement strategies to meet the expectations of its customers (either by developing more bargaining power towards wholesalers to assure supply, or run its own distribution centre to be able to fulfil orders from the pharmacies that join in – both in terms of volume and in terms of lead time fulfilment).

## **CONCLUSIONS**

This research aimed at assessing and comparing the quality of the service provided by the traditional distribution system of pharmaceutical products in Portugal and the one made available by the economic groups that emerged when the industry became less regulated. The assessment was put to practice from the perspective of the pharmacies.

Findings lead to conclude that when managers of pharmacies have more time to dedicate to procurement issues it is possible to achieve better quality of supply (price, lead time consistency and product availability) than the service provided by the wholesales with agreements with the economic group analysed. These issues are the more relevant ones for the pharmacies when assessing their suppliers but the pharmacies of the analysed group need to keep parallel suppliers to achieve the service supply their desire. Product availability issues should be the main focus of the group if it wants to improve the quality of the service provided. Nonetheless the Group is well recognised for the range of complementary services made available for its pharmacies and the marketing support they provide.

A single economic group as analysed and the sample used was limited (only 20 pharmacies). It would be interesting to expand this research to more pharmacies of the same group. In the same line of research, it would be interesting to compare the difficulties of supply of this Group with other economic groups. As the quality of the service provided is better assessed by its customers, further research should be performed to assess if the quality of supply influences customers' perceived quality of the service provided at the pharmacies.

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# **EMPIRICAL BIG DATA ANALYTIC OPERATIONS IN SUPPLY CHAIN MANAGEMENT OF SMALL TRADING COMPANY- CASE OF SMALL TRADING COMPANY IN TAIWAN**

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## **Abstract**

Purpose of this paper:

The objective of this research is to present the empirical big data analytic operation applied in a small firm named A company to improve her operating efficiency and performance.

Design/methodology/approach:

Case study method includes in-depth investigation into A company. Data was gathered from A COMPANY historical business data. Then statistical method (SPSS) is used to analyze the volume data to understand the best inventory level, logistics operations practice and customer analysis.

Findings:

After reviewing literatures and analyzing A companybig data, the findings of this case study revealed the underlying elements which were big data analyzing small trading company and creating the analyzing model A Company.

Value:

This paper deals with A company big data collection, analysis, and interpretation which will contribute to the development in data-driven of supply chain management of trading company.

Practical implications (if applicable):

This study has significant implications for small and medium enterprises called SMEs and for organizations which have to operate supply chain management. SMEs are the main business sectors in Taiwan and they need efficient supply chain management due to the shortage of human power along with the development of good performance of supply chain management. The efficient supply chain management is considered as the key to the success of SMEs.

Key Words: supply chain management, big data

## **Introduction**

No doubt, analytics is the new competitive driver, surely, no field of business operations promises a more challenging contest of applied imagination than supply chain management. Visionary companies in many different industries are already deploying advanced supply chain analytics to gain an edge on their competitors. (Bill Tobey , 2008)

Many business operations are directly built big data analytics as in-line decision support resources for front-line personnel, rather than off-line, after-the-fact tools for management use alone.

More than 13 years operational data of small trading and channel corporate called A COMPANY will be used to analyze the facts of supply chain management and customers including cost variation, purchasing differences, locations, payment term, products, between products and customers, marketing strategies, and logistics operations .

## **Literature review**

Data driven supply chain is an optimized system of supply chain data which improves inventory levels, lower costs, and reduced risks. Without proper integration in internal and external systems, supply chain analytics can be too complex or too costly to control. Supply chain optimization is driven by the demand for efficient use of resources to maximize delivery while minimizing excess and obsolete inventories. By improving demand forecasting systems and integrating supply chain data, risks and costs are lowered. As data volume and sources increase, a quality data system facilitates near real time analytics, reduces costs, and improves delivery. Informed decisions create efficiency in managing supply, SKUs, inventory, and other resources.<sup>1</sup>

Sanders, Nada R.(2016) explored that "big data is properly applied can profoundly influence the marketing, logistics, operations, and sourcing sectors of a supply chain. Marketing has the most developed analytics with the focus on customer demand and behavior; prices can be optimized and customer strategies can be adjusted dynamically. Logistics analytics optimize inventory and resource allocation, identify optimal distribution locations, and minimize transportation costs. "<sup>2</sup>

Digital data are collected by real time information about events in six primary elements which are who, what, when, where, why, and how. Some of events have

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<sup>1</sup> Bill Tobey (2008), "Assembling the data-driven supply chain : Integrated, quality-controlled data boosts operational supply chain analytics" Teradata Magazine September 2008, AR-5710

<sup>2</sup> Sanders, Nada R.(2016), "How to Use Big Data to Drive Your Supply Chain" California Management, Volume 59, Issue 1 ,Fall 2016

multiple attributes for a given element, or no qualities at all for that element. Sanders, Nada R., 2016)

Proceeding the big data driven, sometimes we should overcoming hurdles that one hurdle is "Analysis Paralysis," a fear of starting to collect and analyze data because of the seemingly overwhelming amount of information. Another concern that occurs when there is too many metrics, and can be addressed by planning critically and consolidating to measure relevant performance. Then how to build a Framework is the key process. When applying big data, there is a general framework of segmenting, aligning, and measuring. What are segmenting that is to create optimal supply chain segments with clear attributes, defining focus and competitiveness in terms of flexibility, cost, quality, and time. Alignment is one of the key steps in introducing big data that is the horizontal integration of organizational functions to support segment attributes and competitive priorities rather than producing random, fragmented explorations. Last is measurement is important to develop the right performance indicator (KPI) metrics for segment analysis. (Sanders, Nada R., 2016)

Another important issue is outsourcing of big data analytics. Big data is important for the health and improvement of a company, the reality these analytics are heavy investment. Companies want to adopt the technologies but many lack the capacity to do the analytical work required. Outsourcing is possible to be taken which an external party provides specialized software, additional data bases, or an analytics consultant. (Nada R. Sanders, Ph.D., 2014)

LARRY LEWIS(2014) mentioned "97 percent of executives reported having an understanding of how big data analytics can benefit their supply chain, but only 17 percent reported having already implemented analytics in one or more supply chain functions."<sup>3</sup> Companies are now able to collect and amass a huge amount of data from many disparate sources since changes in technology and digital storage capabilities. How to develop and deploy the right data analysis tools and techniques to mine intelligence from that data, there are a few preliminary steps to gain visibility into your supply chain as the follows:<sup>4</sup>

"1. You must implement the proper controls needed to optimize all of the processes throughout your global network and you have to create a closed-loop process to gain insight into your operations.

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<sup>3</sup> Larry Levis(2014)," How to Use Big Data to Improve Supply Chain Visibility", Talking Logistics with Andrian Gonzalez

<sup>4</sup> Larry Levis(2014)," How to Use Big Data to Improve Supply Chain Visibility", Talking Logistics with Andrian Gonzalez

2. You need to consider what type of business intelligence tool to implement to obtain the visibility you need to measure and monitor your business across multiple workflows. Many companies explore using a point solution to help with data analytics and day-to-day decision making, while others consider an enterprise-wide solution that enables you to capture, process, and deliver insights into key supply chain processes.

3. Understand that true supply chain visibility is an ongoing endeavor as most organizations are unable to see across the entire supply chain. The lack of visibility, or blind spots, is often due to specific events or lack of integration points with trading partners or suppliers. With these blind spots, organizations are unable to drive the proper metrics to manage day-to-day operations and generate significant business value. Collaborating with trading partners and effectively capturing critical data are key elements to the success of achieving your goal of end-to-end visibility.”

Big Data-centric architecture for SCM has been proposed that exploits the current state of the art technology of data management, analytics and visualization. The security and privacy requirements of a Big Data system have also been highlighted and several mechanisms have been discussed to implement these features in a real world Big Data system deployment in the context of SCM. Some future scope of work has also been pointed out.<sup>5</sup>

### **Research design and methodology**

In order to obtain an insight into big data driven in supply chain management, an exploratory approach was adopted for this research. A case study was used for exploring the big data analytics to Improve supply chain cost effective and to increase operational efficiency. Using a volume data of case-a small trading company called A COMPANY is to explore her operational process of supply chain management and customer. Using the statistical software SPSS to analyze volume data then try to understand cost, logistic operation cost and efficiency, product change, their relationship, and etc.. Big data consists of expense of sales, revenue, profit, logistic service cost, inventory cost, logistic time, procurement process and cost, products. The result will be used to make the right decision of supply chain process and best policies of supply chain management.

### **Analysis**

#### **1. Introduction to Research Firm**

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<sup>5</sup> Sanjib Biswas, Jaydip Sen(2016), “A Proposed Architecture for Big Data Driven Supply Chain Analytics”, International Journal of Supply Chain Management (IUP), June 2016

A company is located at Kaohsiung Taiwan. Its business consists of international trade, logistics services and consultancy. A Company income was about one million from 3PL services and about two and half millions every year created by 2~3 staffs.

(1). Core competence of A Company

Well-qualified human resources and well-qualified value chain of logistics service such as customs broker, transportation, forwarder, warehouse, IT service provider, insurance, bank, and so on are A COMPANY's partners. James Lee is the president of A Company who is an integrated international logistics specialist and a professional of international distribution management. All A company's staffs have much and long experience in logistics service.

(2). A company 3PL operational Model (Fig. 1)

A company 3PL operational model, According to experience and in-house resources an operational model to provide great service for SMEs will be explained as the follow. Good IT system, experienced and integrated capability staffs, and experienced logistics service providers are basic team members in this operational model. Naturally, highly efficient & standard operation procedures being formulated are very important.

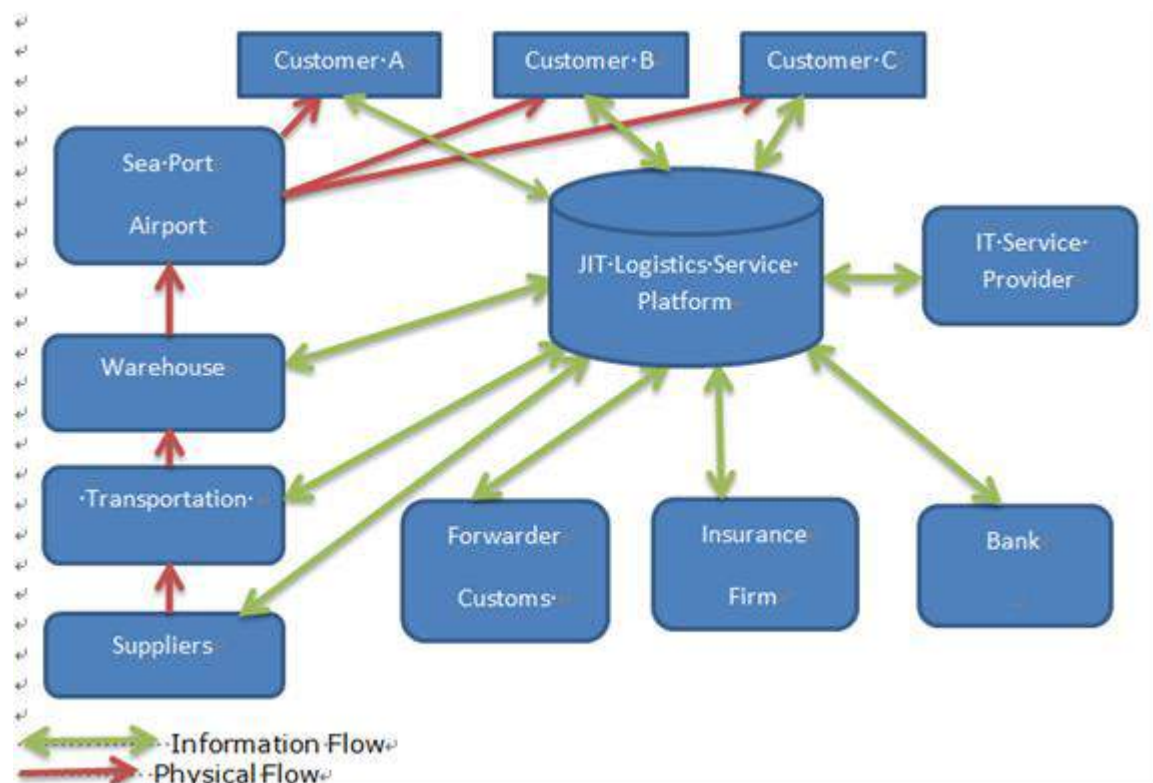


Fig. 1: A COMPANY 3PL Operational Model

## 2. Big data analysis

Using more than 13 years data consists of business revenue, product change of time series, logistic service fee, customers' orders, location of customer, cost variation, so on. In this research, business transformation, cost of logistic service, and operational process will be explore through the data analysis. The results will be display as the following charts.

### (1) Product change

Product	Electronic	Biotech	Logistics Service	Hardware	Commodity	Others (Management Service,.....)
Year						
2004	80%	0%	3%	10%	5%	2%
2005	85%	0.2%	4.8%	6%	3%	1%
2006	75%	3%	5%	12%	2%	3%
2007	52%	5%	13%	8%	10%	12%
2008	40%	12%	12%	5%	12%	13%
2009	48%	11%	10%	11%	10%	10%
2010	44%	15%	11%	10%	6%	14%
2011	36%	19%	15%	10%	8%	12%
2012	32%	20%	18%	8%	12%	10%
2013	24%	32%	14%	10%	8%	12%
2014	30%	35%	10%	5%	7%	13%
2015	10%	42%	11%	8%	13%	16%
2016	10%	45%	15%	5%	5%	20%

Analysis

Biotech is more important product, then management service and logistic service.

### (2). Countries

Countries	Taiwan	USA	Africa	Europe	ASEAN	Other (South America,.....)
Year						
2004	70%	2%	5%	3%	13%	7%
2005	65%	5%	5%	5%	15%	5%
2006	70%	6%	4%	7%	12%	5%
2007	55%	10%	3%	2%	18%	12%

2008	45%	8%	7%	8%	20%	12%
2009	40%	10%	5%	5%	25%	15%
2010	37%	15%	8%	10%	28%	12%
2011	30%	16%	4%	12%	30%	8%
2012	28%	12%	5%	10%	35%	10%
2013	25%	10%	5%	10%	45%	5%
2014	25%	8%	7%	12%	38%	10%
2015	18%	20%	4%	15%	40%	3%
2016	15%	18%	2%	15%	40%	10%

Analysis-Taiwan is less and less, ASEAN countries is more and more

Why no China? Bad experience made us not do business with China.

### (3). Cost Analysis

Cost	Logistic	Product	Sales Expense	Human Resource	Others	Gross Profit
Year						
2004	17%	53%	5%	5%	1%	19%
2005	17%	52%	4%	6%	1%	20%
2006	16%	51%	4%	5%	2%	22%
2007	15%	50%	5%	5%	1%	24%
2008	15%	48%	4%	3%	2%	28%
2009	14%	47%	4%	4%	2%	29%
2010	14%	47%	4%	4%	1%	30%
2011	13%	47%	4%	4%	2%	30%
2012	13%	48%	4%	4%	2%	29%
2013	12%	40%	4%	3%	2%	35%
2014	12%	40%	3%	4%	3%	38%
2015	11%	45%	4%	4%	2%	34%
2016	11%	44%	4%	4%	2%	35%

Analysis

Logistic service cost is lower, product cost is lower, gross profit is higher.

### Conclusion

1. The main findings from analyzing the empirical data and the existing theory are in order to understand the practical current business status as the follows:

- (1). Logistic cost is at least 11%.
- (2). Product change will be lower cost and higher margin.
- (3). More sales in ASEAN countries.
- (4). Sales cost and labor cost is keeping stable.

- (5). Business with China is not our target since credibility and honesty.
- (6). The business direction meets the government policy.
- (7). Outsourcing strategy is the right policy.

2. From the finding we made our policies as the follows:

- (1). Investing IT system in SCM is more important issue.
- (2). Gross margin is at least 30% and up.
- (3). In the small trading company, labor cost should be lower than 5%.
- (4). Biotech product and managed service are higher margin.
- (5). USA, ASEAN countries, European countries are the main market.

To meet the above policies, we found that labor quality, SCM capability. CRM will be the key issues now. The market research is the most important thing before kicking off the market.

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# **THE KEY TO SUCCESSFUL OPERATIONAL DUE DILIGENCE: THE RIGHT DATA, AT THE RIGHT TIME, ANALYZED IN THE RIGHT WAY**

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## **ABSTRACT**

An operational due diligence is characterized by a short timeline and the need for expert knowledge. These two aspects have a tremendous influence on both the acquisition decision and the overall success of an merger and acquisition (M&A). Consequently, a profound assessment of a target company's operational potentials and risks held against the future performance expectations is considered pivotal. However, this theme is to a great extent unexplored in extant literature. This paper describes both qualitative and quantitative operational factors influencing the acquisition decision in the operational due diligence phase of a M&A.

## **INTRODUCTION**

In the last five years, mergers and acquisitions (M&A) has increased, although the overall success rate have been inferior (Institute of Mergers, Acquisitions and Alliances, 2016). Therefore, it is essential to identify the target company's operational drivers as they contribute to M&A success (Herd, 2004). Increasing complexity and dependency in a target company's operating model, such as distribution networks, supplier relations and IT systems, continue to become more important to identify and understand (Malik, 2011).

Traditionally, the legal and financial due diligence have been the main focus in the M&A due diligence process (Grebey, 2012). These due diligences provide insights in obligations, contracts, cash flow, assets, financial statements, etc. but omit the operational aspects (Shaughnessy, 2009). Neglecting or deprioritizing the operational assessment can prompt vital consequences, such as unforeseen delivery issues, for the acquisition. The operational insights have multiple influence points such as the valuation of the target company, leverage in price negotiations, the integration process, and the improvement potentials (Herd, 2004).

The aim of this paper is to explore the operational drivers influencing the acquisition of a target company. Furthermore, this paper aims to structure the drivers into a normative framework that supports the operational M&A advisors in performing an effective operational due diligence, while providing acquirers with well-informed and deliberate decision foundation prior to the acquisition.

This paper use the expression operational factor as a component influencing the target company's operating model in either a positively or negatively way. In addition, a simplified definition of Grebey (2012)'s organizational scope of an operational due diligence is applied. It includes *Sourcing, Manufacturing, Distribution, and Logistics*.

## METHODOLOGY

Due to the complex nature of the research aim, a qualitative approach is used to provide rich and in-depth data. The explorative approach of the study allows for thorough understanding of the research area. Therefore, the case-study approach is the most appropriate research methodology (Yin, 2013).

To get insight into the M&A practitioners experience and obtain more detailed and in-depth data, semi-structured interviews were conducted with several practitioners, both acquirers and advisors. The acquirers were chosen based on set of key parameters including (i) having experience with acquiring international companies, (ii) being part of multiple operational due diligence cases, and (iii) acquired companies with a production of physical goods and a supply chain. The advisors were also selected based on a set of key parameters including (i) having performed more than three operational due diligences, (ii) having financial insights, and (iii) deep operational expertise within the supply chain. Furthermore, both practitioner roles argue that a better understanding of the operational due diligence process is crucial. Collectively, 11 interviews were conducted with five acquirer interviews and six operational M&A advisor interviews. In total, the interviewees have conducted more than 120 operational due diligence projects.

The research is divided into four key phases. Firstly, an extensive literature review of research papers and industry publications were conducted. The number of articles identified in the initial research counted 131. Through a screening process, with a range of exclusion criteria's including a) Cultural Due Diligence, b) Hedge Fund Operational Due Diligence b) Technical Due Diligence, the number of articles was reduced to 42. Furthermore, a detailed examination of the remaining articles led to a final list of 22 articles. Secondly, semi-structured interviews with several M&A practitioners were conducted and the qualitative data was analyzed by coding and subsequent a factor frequency analysis. Thirdly, structured comparison of the literature and the empirical data was completed. The last and forth phase concern the development of a normative framework that supports the acquirers and advisors in performing an operational due diligence.

The data and information used for this paper were collected from acquirers' and advisors' previous experience with operational due diligence cases as a part of an M&A process. The research team worked in close collaboration with the advisors, as they function as the executing part of the operational due diligence. The semi-structured interviews provided key insights in analysis and the practicalities of an operational due diligence. Combined with the literature review, this method enabled triangularity between the extant literature and the empirical data, hence strengthening the validity.

## LITERATURE REVIEW

The extant literature proposes a value chain perspective to assess the target company's operational setup (Recardo, 2014). This approach helps comprehending the individual elements of the supply chain and it helps mitigate the risk of disregarding essential insights in the operating model. Grebey (2012) compartmentalize the organizational scope of the operational due diligence into six functional areas. The respective areas are 1) R&D, 2) Sourcing & Procurement, 3) Manufacturing, 4) Warehousing & Inventory, 5) Transport & Logistics, and 6) Sales & Marketing. The organizational scope of the operational due diligence is in this paper a limited version of this definition, as R&D and Sales & Marketing are excluded as shown in Figure 1.



Figure 1: Operational Due Diligence Scope

To identify the theoretical operational factors within the operational due diligence, a comprehensive analysis of the extant literature have been conducted. Generally the

literature categorizes the factors into six groups. These groups include 18 operational factors collectively and each factor is considered to have a significant impact on the acquisition decision. Table 1 displays the resulting operational factors found through the literature review.

*Table 1: Operational factors for M&As*

Operational Factor Groups	Operational Factors	Literature Reference
<b>People &amp; Organization</b> <i>How does the people and organization accommodate the operational strategy?</i>	Capabilities	Recardo (2014), Alvarez (2007), Grebey (2012), Ahammad (2013), Shaughnessy (2009) .
	Organizational Structure	
	Personnel Infrastructure	
	Corporate Culture	
<b>Information Technology &amp; Systems</b> <i>What IT and systems are deployed, and how are they used?</i>	Data	Grebey (2012), Recardo (2014), Morrison (2008), Ahammad (2013).
	Systems	
	Tools	
<b>Costs &amp; Capital</b> <i>How is the operating costs and capital structured?</i>	Operating Costs	Clayton (2011), PwC (2016), Recardo (2014), Anklesaria (2007), Alvarez (2007), Cooper & Kaplan (1991).
	Assets	
<b>Scalability</b> <i>How scalable is the target company?</i>	Competencies	Morrison (2008), Emerald group (2004), Shaughnessy (2009), Tompkins (2012), Rothenbücher (2008), Herd (2005), Recardo (2014), The Boston Consulting Group (2015), Shaughnessy (2009), Alvarez (2007).
	Capabilities	
	Technologies	
<b>Potentials</b> <i>What are the optimization potentials?</i>	Rationalization	Clayton (2011), PwC (2016), Recardo (2014), Anklesaria (2007), Alvarez (2007), Cooper & Kaplan (1991).
	Efficiency	
<b>Risk</b> <i>What are the risks that might compromise the current and future operations?</i>	Materials, assets, goods	Tompkins (2012), Grebey (2012), Herd (2005), Rothenbücher (2008), Recardo (2014), The Boston Consulting Group (2015), Shaughnessy (2009), Alvarez (2007).

Even though the literature present a scarce amount of information on operational due diligence, it was possible to identify a sufficient amount of operational factors concerning the operating model of a target company.

## EMPIRICAL FINDINGS

To obtain more rich and qualitative data several interviews were organized with both acquirers and operational M&A advisors. A coding and a frequency analysis of the interviews enabled a quantification and identification of the operational factors and their the relative importance. Furthermore, the analysis subsequently supports the development of a normative framework. The coding identified 222 operational factors accentuated in the

empirical data. Through several iterations, the individual factors were evaluated and consolidated if equivalent interpretation occurred. Throughout the analysis, duplicates and substituting factors were eliminated. The analysis reduced the number of factors from 222 to 27 operational factors. To assess the importance, the operational factors were scored by their mentioning frequency across the interviews. The factors are grouped based on similarity and context, and listed in Table 2 ranked after highest frequency first.

Table 2 : Operational factors from interviews

Operational Factors		Score	Operational Factors	
People & Organization	Leadership & Strategic Competencies	93%	93%	Efficiency & Flow
			93%	Operational Planning
	Employee Capabilities	85%	85%	Uptime, Maintenance & Lifecycle
	Organizational Structure	72%	72%	Quality Management
	Personnel Infrastructure	57%	66%	Delivery & Service Levels
	Corporate Culture	11%	66%	Capacity Utilization
			57%	Company Footprint
Costs & Capital			36%	Outsourcing & Offshoring
	Net Working Capital	100%	43%	Approvals & Certifications
	Capital Expenses	93%	20%	Health and safety
	Operating Expenses	93%	11%	Governmental Restrictions
Data & Documentation	Cost of Goods Sold	66%	11%	Corporate Social Responsibility
	Data Quality & Availability	40%	70%	IT Systems Maturity
	Key Performance Indicators	28%	43%	Technology Utilization
	Process & Project Documentation	28%	28%	Degree of Automation

The operational factor group *Cost & Capital* is the most frequently occurring across all interviewees, which emphasizes the necessity of assessing the target company's cost structure. Furthermore, the operational factor *Net Working Capital* is in immense focus, due to the importance of understanding the cash conversion cycle and opportunities to free up cash. Another operational factor group, with relatively high focus is the group *Planning, Efficiency & Quality*, which includes the more classical operations elements. These underlying factors are generally underlined as having significant potential for operational improvement by several of the interviewees. The group *Politics & Regulations* received the overall lowest attention even though some interviewees mentioned the factor *Approvals & Certification* as being a potential deal breaker, hence it is critical for the final acquisition decision. However, it was simultaneously concluded that this factor is highly case dependent and appears infrequently.

Generally, the majority of interviewees consider a common approach with two high level perspectives for the operational due diligence. Firstly, a risk perspective and secondly an improvement potential perspective. These two perspectives help clarify key insights to in the pre-acquisition process, since they helps quantify the return on investment, mitigate uncertainty, prevent unexpected post-acquisition investments, etc.

In addition, two guiding factors with distinctive character were mentioned by multiple interviewees. The factors intersect the entire supply chain and several of the previously defined factor groups, namely the target company's ability to scale and its maturity. As these two factors support the holistic picture of the company they are denoted as highly important to incorporate as part of the operational due diligence. For example, the procurement process's maturity level and the ability to scale the production output are two ways of understanding the target company. Two other and more case-specific factors that were mentioned in the interviews are consolidation and synergies. These are highly influenced by interlinkages and often only considered in merger cases.

Ultimately, all interviewees consider the operational due diligence's organizational scope as the supply chain, separated into components as *Sourcing & Procurement*, *Manufacturing/Production*, *Warehouse & Distribution*, and *Logistics & Transport*.

## **COMPARATIVE ANALYSIS**

When comparing the extant literature and the empirical data, a noticeable correlation is apparent. However, where the literature only address the subjects superficial, the empirical data are much more detailed and practically oriented in the description of the operational due diligence. The incomprehensive theory fall short in the level of detail and research quantity within the subject of operational due diligence. Furthermore, the empirical data provides several additional operational factors and more depth, which fortify the purpose of the research in this paper on operational due diligence.

One of the major differences is the maturity factor, which is almost non-existing in the extant literature. The interviewees use this as a metric for quantifying the current state of the target company's operating model. This factor cut across multiple operational factors and is expressed as being vital instrument for the operational due diligence.

Both the extant literature and the empirical data point to the significance of understanding a target company's People & Organization. However, the interviewees distinguish between the workforce competencies and the executive leadership competencies, while the extant literature presents a more holistic perspective. In addition, the empirical data supplement the literature with several operations management factors to be incorporated in an operational due diligence context, among these are Operational Planning, Efficiency & Flow, Quality Management, etc.

Generally, the literature does not include information on where to find data or which analysis that needs to be conducted. Therefore, the empirical data were crucial in order to obtain more knowledge about the individual factors, which is necessary to develop a normative framework for the operational due diligence process.

## **A NORMATIVE OPERATIONAL DUE DILIGENCE FRAMEWORK**

A common characteristic in the extant literature and the interviews is the recommendation of utilizing a structured approach when performing a operational due diligence. The strict timeline during operational due diligence process require a simple approach driven by factors and include iterations. Conclusively, an efficient and comprehensive procedure is proposed as a normative hypothesis driven framework with knowledge from both literature and practitioners.

In figure 2, a framework incorporating findings from literature and expert interviews are is presented. The framework helps identify important insights influencing the acquisition decision through operational key questions and associated analyses.

Figure 2 – Framework for operational due diligence

Operational Factor Groups	Operational Key Questions	Primary Analysis
People & Organization	<i>Does the executive management have the ability to lead and execute the future strategy?</i>	Leadership capability assessment
	<i>To what extend is the current workforce capabilities able to support the future operational performance?</i>	Workforce flexibility, training, capacity assessment
	<i>Are the organizational structure ready</i>	Organization Diagram
	<i>Does the organization have a suitable personnel infrastructure?</i>	Absence, churn, salary, etc. analysis.
	<i>To what extend do the corporate culture support continuous improvement?</i>	Mapping of continuous improvement (kaizen) process, board meetings, etc.
Costs & Capital	<i>How well are net working capital managed?</i>	Inventory coverage analysis and DIO, DPO, and DSO assessment.
	<i>How well are capital expenditure managed?</i>	Review of previous and future CAPEX investment requirements
	<i>How well are operational expenditures managed?</i>	Identify cost drivers and map OPEX development
	<i>What is the breakdown of the cost of goods sold?</i>	Identify cost drivers and map COGS development
Data & Documentation	<i>Are sufficient amount of data available in the right quality?</i>	Data sample and measuring test
	<i>Does the organization have a set of KPI's that describes and track the operational performance?</i>	Review of KPI structure and monitoring process
	<i>How well are processes and projects standardized and documented?</i>	Review quality and system for project charters, SOP's, etc.
Planning, Efficiency & Quality	<i>Does the operational processes have a sufficient efficiency level and strive toward optimal flow?</i>	Analysis of OEE, bottleneck, lead time and throughput
	<i>To what degree is operational planning established and aligned across the supply chain?</i>	Review of S&OP process, inventory control and forecasting, etc.
	<i>What is done to ensure that facilities and machineries are in good condition and available for current and future usage?</i>	Evaluation of maintenance program and planning
	<i>How well is quality managed?</i>	Assessment of quality control process (rework, fail rate, scrap rate, etc.)
	<i>How well are delivery and service levels managed?</i>	Evaluate delivery performance vs. service levels
	<i>What is the capacity and utilization level?</i>	Quantification and mapping of capacity vs. utilization
	<i>How well does the operational footprint match the demand?</i>	Mapping and evaluation of footprint vs. demand
	<i>To what extend are outsourcing and offshoring activities utilized?</i>	Review Make/Buy decision process and opportunities
Politics & Regulations	<i>Are approvals and certifications in possession of the organization?</i>	Review of current and future requirements for approvals and certifications
	<i>Are necessary health and safety regulations established and maintained?</i>	Assessment of HSE requirements vs. current conditions
	<i>Are governmental restrictions barrier and are they respected?</i>	Review of historical and potential future governmental restrictions
	<i>What is the company policy for the corporate social responsibility?</i>	Evaluate the CSR vs current conditions
Technology & IT Systems	<i>How mature and how well are the IT systems used to leverage operational benefits?</i>	IT maturity assessment
	<i>To what degree are relevant technology utilized in the supply chain?</i>	Review of current technology vs. new opportunities
	<i>To what extend are processes automated?</i>	Assessment of automation degree

To set the acquirer in an optimal position before the final negotiation, the acquirer must have comprehensive insight in the target company's current and future risks and potentials. The framework builds on six swim lanes, each with an operational factor group. The individual swim lanes contain key questions that addresses the operational factors in the supply chain. To answer these key questions and obtain the right data on target company, a proposed analysis is associated to each question. The list only contains the primary analysis and are not an exhaustive list. Consequently, the practitioner needs to ensure the analysis are in context to the case. As a supplement, the practitioner should assess the target company in terms of maturity and its ability to scale.

In the operational due diligence process, the practitioners must balance obtain data from multiple sources in order to gain sufficient understanding of the target company's operating model. Typically, two situations occur either 1) scarce amount of data or 2) data abundance. It is crucial for the practitioners to obtain the right data through the right source. The framework assists the practitioners in selecting the right question, while the data are available from five sources:

- Publicly available data/information such as financial statements, news articles, press releases, etc. – *Often used in the early stage of the due diligence to get an initial understanding of the target company.*
- Investor memorandums and management presentations – *The first information received from the target company. Valuable data that often are used as foundation for the hypothesis.*
- Site visits – *The practitioners normally have access to one site visit per site in the due diligence process. This is a crucial part of process, since it provide deep insight in the production setup, flow, culture, etc.*
- Interviews – There are typically one or more Q&A sessions either through psysical interviews or via telephone. This data source pose an opportunity to get answers to key questions and assess the target company's people competencies.
- Data room (data requests & questions to management and/or staff) – *Data is available in the data room. But often is it irrelevant, redundant and overloaded. Therefore is it important to request specific information to perform analyses or answer questions.*

Finally, based on information and data received from the five sources, the primary analyses can be performed. The analyses are an instrument to confirm or reject the hypothesis, and the results hereof function as a powerful aid in the final negotiation and acquisition decision.

## **DISCUSSION**

The extant literature suffers from a large research gap. Both the depth and the quantity of operational due diligence theory are immensely scarce. Hence qualitative data consisting of interviews with both acquirers and operational M&A advisors are crucial to obtain a sufficient understanding of the target company's operating model. While the literature recommends a structured approach, no theoretical framework exists. The research contributes to the literature with a structural approach and are the foundation to an effective and thorough operational assessment process. However, the interviewees express that obtaining full benefit of the framework, require that the team, allocated to the operational due diligence, have competent proficiency and experience within operations management and possess a solid financial understanding.

Since the operational due diligence cases are characterized by being case specific, a generic framework functionality can be questioned. Nonetheless, the importance of having a strong point of origin and a structured approach are expressed in both the theory and the empirical data. Hence, the framework accommodate the need for a structured approach to excel operational due diligences.

## CONCLUSION

The aim of this paper was to investigate the operational factors influencing the success of M&As. To achieve this, the operational factors were identified and structure them in a normative framework to develop a solid basis and guideline for conducting a successful operational due diligence. A comprehensive literature review was performed and supported with 11 interviews with acquirers and advisors. While the explorative literature review established a foundation for the understanding of operational factors, the semi-structured interviews provided more comprehensive and thorough knowledge of both the data gathering process, the operational drivers, key questions and finally, analyses, which collectively provide an approach to the operational due diligence.

In total, 27 operational factors were identified based on the consolidation of extant literature and empirical data. Each operational factor is expressed with a key question to help the practitioner identify the target company's risks and potentials.

Conclusively, a normative framework for supporting the practitioners in the operational due diligence process was presented. The framework creates a foundation for hypothesis development and helps focus on the most important key questions that need to be answered. With increasing merger and acquisition activity and growing complexity in supply chains, a normative framework supporting the time pressured process of operational due diligence is more important than ever.

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# **IMPLANTATION CHALLENGES AND RESEARCH OPPORTUNITIES IN BIG DATA ANALYTICS FOR MANUFACTURING ENTERPRISES**

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## **ABSTRACT**

In the past two decades, manufacturing enterprises have been creating large databases due to various global operations within their Enterprise Resource Planning (ERP) systems. However, it has only been over the past few years where companies are experimenting with the concept of Big Data Analytics (BDA) to explore and exploit massive data sets to identify trends and develop models for prediction of future business ventures and enhancement of productivity and profitability. In reality, the field of professional and academic research in BDA is fairly young. Consequently, the current research coupling the manufacturing enterprises to the BDA field is neither rich nor expansive. There are a number of opportunities for BDA research in the entire range of ERP operations. However, in order to conduct value-added research in this area, the ERP and BDA experts must be exposed to each other's knowledge domain. Furthermore, the research contents must have rigor, depth of concept and findings must be disseminated in a detailed and transparent format for other researchers and practitioners to replicate such models. This article attempts to bridge the research gap in this field and makes a number of recommendations for future work in BDA research as applied to the ERP domain.

## **Introduction**

After two decades of experience in implementation of Enterprise Resource Plan (ERP), presently the global manufacturing enterprises face a new, complementary and consequential challenge. In just the past few years, the concept of Big Data Analytics (BDA) has become a competitive factor in business analysis at operational, tactical and strategic levels of decision making. According to McKinsey & Company (Susan, et al, 2013), for manufacturing companies BDA has the potential of total productivity gain of \$270 billion in production, supply chain and R&D. Furthermore, as reflected in a report by Ziff Davis (2014) there is a prediction of 50% faster growth for companies who invest in and utilize BDA. Additionally, approximately 64% of supply chain executives look at BDA as a disruptive technology and business approach to achieve long-term business goals.

Contrary to the above strong testimonies by the industrial leaders, the same report indicates that companies do not use more than 12% of the available data within their enterprises. Despite the fact that BDA is indeed a futuristic approach to conduct business, 67% of industry leaders have revealed the large investment cost to be the top concern against deployment of BDA (Accenture Report, 2014). The associated costs are presumably due to the IT infrastructure, BDA tools and software, and the cost of consulting or employment of teams of data scientists. However, the same report shows interesting results based on a survey of 1014 global enterprises across North America, Europe and Asia Pacific, where 50% of them were manufacturing enterprises. Results indicate that 46% of those companies that utilize BDA improve their customer service and demand fulfillment by 10% or more while 41% have achieved a more effective responsiveness to supply chain variabilities. This study revealed two more valuable organizational findings. One result showed that an imbedded culture of daily usage of BDA is significantly more effective in every aspect of business analysis than an ad-hoc approach in utilizing BDA. The second

finding revealed that for 10 different supply chain KPIs, companies with teams of dedicated data scientists who facilitate and assist in business supply chain decisions by far performed better than those companies who utilize traditional database teams and personnel.

The above testimonies are provided by the leaders of industry. The question is, then, what are the recent contributions by the academic and professional researchers in the field of BDA? Our research indicates that there is a significant shortage of quality publications that indeed provide tangible, field tested and replicable methodologies in BDA. Instead, most of the disseminated information are conceptual and hence may not provide much practical value. In an excellent literature review and descriptive analysis, Brinch (2017) has identified 43 articles in BDA that are related to supply chain management, where almost half of them are conceptual in nature. Furthermore, 27 out of 43 papers propose and apply different methods for BDA but often do not utilize a thorough data collection and hence the validity of results may be doubtful. The conclusion of the article by Brinch is that theoretical grounding and methodological rigor of the currently available publications in BDA applied to supply chain research are weak.

The shortage of rigorous, rich-content BDA research in supply chain management seems to be even much more apparent in the other business aspects of ERP. That is, the remaining modules and levels of ERP from Sale & Operations plan at the business front-end extended to production planning, master scheduling, material requirements planning, capacity planning and the scheduling of manufacturing operations at the business back-end show even more absence of value-added research than in supply chain management. Furthermore, most of the papers by business practitioners emphasize on the results rather than the process details by which their BDA projects were conducted. One reason may be that in order to gain both theoretical and practical knowledge in BDA, the data scientists need to extend their domain knowledge of supply chain and other manufacturing enterprise functions and principles. At the same time, the supply chain personnel and teams must increase their understanding of and exposure to the principles of BDA (Walter and Fawcett, 2013). However, according to interviews with our industry affiliates, the concept proposed by Walter and Fawcett should not be limited to the function of supply chain management. Rather, it must encompass all business aspects of manufacturing enterprises.

In addition to the weakness of research rigor and the shortage of knowledge domain among the supply chain/ERP staff and their BDA colleagues, the company's culture and structure to promote and support a proactive and enterprise-wide approach to BDA seems to be a challenging obstacle (Leveling, et al, 2017). As previously stated, the implementation cost of BDA infrastructure is reported to be a significant deterrent in BDA deployment in industry. Additionally, and unfortunately, some of the business leaders believe more in a "gut feeling" than a data driven approach to business (<https://www.gyro.com/onlyhuman/>).

The above findings reveal that field of BDA is indeed an open avenue for scientific research, both in technical aspects of BDA as well as the organizational and cultural issues of business enterprises. The objectives of this paper are three folds. First, it will provide a rather summarized exposure to the process of dealing with typical BDA. The second objective is to offer recommendations for future research areas to fill the gap in the manufacturing enterprise BDA model building and decision making. Finally, the third goal of this paper is

to make a list of recommendations for the future BDA research community to disseminate certain critical contents in their reporting system to benefit the future research projects.

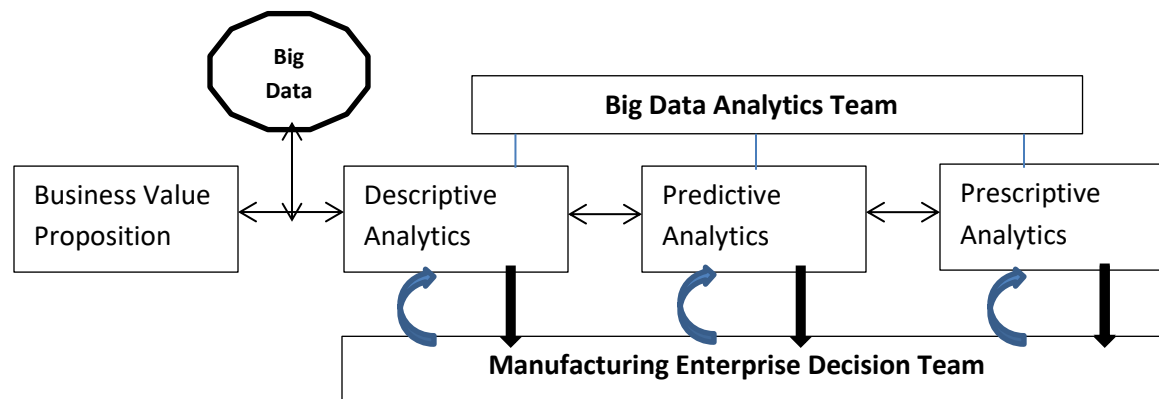
### Basics of Big Data Analytics

Manufacturing enterprises have historically used the power of analytical decision making to resolve business problems and opportunities. These analytical methodologies have included a variety of operations research, simulation/computer models, statistical and management science concepts and tools to assist the practitioners in objective decision making. Currently, however, the companies are facing a new challenge, and a different one than the traditional approach, for solving business problems: BIG DATA. There are five characteristics of big data (known as 5 Vs) that need attention. **Volume** of data is the first eye opening factor. It typically starts at the Terabyte level (1,000GB) and moves to Petabyte (1,000TB), Exabyte (1,000 PB), Zettabyte (1,000 EB), and Yottabyte (1,000 ZB). To have an idea about the monstrous size of such big data, the total volume of data from the entire catalogued books in the U.S. Library of Congress amounts to 15 TB (The Economist, Feb. 25, 2010). As a side note, a high tech company revealed to these authors that if one can transfer a given data set into her/his laptop, it is not considered to be a big data. The next V is the element of **Variety** which refers to not only the quantitative data but also qualitative, text, social media, imageries, voice, video, and sensor data, which are often referred to as unstructured data. The variety dimension has created formidable challenges for the data scientists and the associated software tools and programming/coding to handle the big data. **Velocity** is the third element of big data and it refers to how fast the companies who are facing the massive volume and variety of data can generate/collect, move around and utilize the data for their decision analysis. The next factor is **Veracity** which refers to the accuracy and quality of data where the question may be if the data set is trustworthy for further processing. Finally, the factor of **Value** is the fifth element of big data which in the opinion of a seasoned analyst is the most critical issue as it poses a specific and objective oriented question as why should one tackle the big data in the first place. Several companies have reported to these authors that the value proposition must be formulated up front at the gateway of business analysis by the BDA team to justify the complex, lengthy and iterative process of big data analytics. Indeed, it is truly this factor that the manufacturing enterprise decision maker, such as the supply chain analyst, and the data science team must begin their collaboration and team approach in their iterative process of business problem solving.

Handling big data is not exactly a science yet and we are just at the tip of this revolutionary approach to business decision making. The variety of newly designed, created and promoted software tools and IT supportive infrastructures makes it rather challenging to recommend a fixed way of approaching the BDA opportunities. However, currently in this field a number of academic institutes have developed a variety of courses and programs often referred to Data Science (DS). Most of these DS curricula are naturally rigorous and highly valuable on the technical part of the BDA. Some schools of business, additionally, do include certain business aspects of BDA and yet there seems to be a lack of manufacturing enterprise models where the business values, goals and objectives are systematically integrated with the BDA process. Figure 1 shows our proposed model to serve as an initial step for a dialogue among researchers and practitioners in this field. This conceptual model has been inspired by reviewing a number of academic DS programs as well as interviewing several BDA experts in manufacturing enterprises.

There are three important observations about this model. First, the process must begin with a well-defined business proposition or question where all customers and objectives

must be identified and that BDA process will not begin unless the enterprise poses that value proposition to the BDA team. Second, the entire process is an integrated and joint effort by the BDA and the manufacturing enterprise teams. And third, the process is iterative from the beginning to the end. Undoubtedly, the BDA team has a superior technical knowledge of the DS methods and tools. However, the results of its findings on each of the three stages must be communicated with the business decision makers for their feedback as new discoveries from the data may indeed modify the original business question by adding more value to it.



**Figure 1- Integrated Big Data Analytics and Business Process Improvement**

The BDA team first cleans the data to observe meaningful categories, clusters, trends or anomalies. This state is called **DESCRIPTIVE** stage and requires much data mining, data warehousing, database management techniques and data visualization. The results will provide clues as how the enterprise is currently doing in regards to the posed question by exploring business trends and patterns. The next step, **PREDICTIVE** analytics, often utilizes statistical models, neural network, Bayesian analysis, Monte Carlo simulation and specialized algorithms to provide insight as how and what the future will be like. Finally, the **PRESCRIPTIVE** analytics stage uses sophisticated optimization techniques and artificial intelligence to recommend what are the best courses of action the business analyst should pursue. This last stage is probably the most important and complex aspect of the BDA process but unfortunately very little research is conducted here. Furthermore, only 3% of business practitioners seemingly explore this stage (LeHong, Fenn, 2013).

In addition to a number of software and IT tools utilized at all three stages, two programming languages are very popular in BDA, especially in Descriptive analytics stage. One is **R** which can be written by integrating different existing scripts. It is very powerful in graphical capabilities and statistical analysis but the drawback for **R** is its lack of high security. **Python** is the second popular language in BDA due to its ease of learning and IoT applications. Its relative drawback seems to be the speed of execution (Krill, Feb, and June 2015).

### **Potential BDA research opportunities in manufacturing enterprise**

With BDA being an emerging and disruptive technology, it is vital for the research community to have guidelines and examples to follow so that further research can effectively assist manufacturing enterprises to implement BDA projects. The future research in this area should have depth, rigor and practical relevance to validate that the proposed models are replicable in other research or practices. Otherwise, it is difficult to justify the risk and cost of BDA applications in manufacturing enterprise if tangible benefits are not found in literature. For example, research conducted in steel processing industry resulted in a conceptual model for processing over 50 TB of data collected from 1.5 million sensors in real time (Krumeich, 2014). The paper covers the technical and management changes a company should undergo to take advantage of BDA in a manufacturing enterprise. However, no practical applications are offered. As a contrasting example, specific research in semiconductor industry describes the use of data mining to improve the fault detection at various manufacturing operations (Chien, 2014). This paper develops a clear methodology for utilizing BDA and provides a detailed account of a practical test case and validates the results rigorously. Unfortunately, the type of informative and replicable research as depicted by Chien is in minority and we need more research of this caliber.

As previously suggested in the INTRODUCTION section, we have opportunities in BDA research from the front-end to the back-end of the manufacturing enterprise. A short list includes: customer relations management (CRM); demand forecasting; sales and operations planning; production planning and master scheduling specially in the complex environment of custom manufacturing; MRP and supportive capacity planning; manufacturing execution system (MES); supply chain management; quality control; machine maintenance; and field services. With the exceptions of a number of BDA research in CRM (but mostly for service companies), several in supply chain management (Brinch, 2017), and a few in sales forecasting, almost all of the remaining above manufacturing enterprise topics beg the attention of future research projects. As an example, with the applications of sensors and RFID technology BDA researchers can collect massive data to assist the MES function to resolve and predict manufacturing lead times, machine up-times, product yield information, and WIP tracking. All these parameters can assist the management in responsiveness to the dynamics of the market place and customer requirements. In another example, one of our high-tech industrial affiliates has reported to us that they receive millions of customer inquiries from the field regarding the failure, quality and reliability of their products. These data can then be used through BDA data wrangling and eventual statistical predictive model building to gauge the relations between the quality of the outgoing products and their probable failure in the field. It is hoped that future BDA research provides us with value-added guidelines and examples to significantly increase the productivity of the manufacturing enterprise operations management.

### **Recommendations for future research contents dissemination**

In addition to the above potential areas of research, the end results of these projects should be disseminated in such a way that they would promote and provide additional opportunities for continuing research either in the complementary or advanced areas of BDA research as applied to manufacturing enterprise decision making. As such, and due to a high level of variety of methodologies, software and supportive IT tools in BDA field, the resultant research publications should be clear and reported in such a manner to enable the future researchers to replicate similar projects in their companies or academic institutes. The following statements, therefore, are suggestions for fellow researchers to cover while disseminating the results of their research projects.

- The business proposition, or the question, that prompts the BDA process should be clearly stated. Any related short term and/or long term objectives must be articulated, along with any KPI, if applicable. All affected customers must be

identified as they do have important roles in the BDA process. And were the objectives achieved?

- What was the original size of data? What were the specific data types (Structured, semi-structured or unstructured)?
- In Descriptive stage, the details of data cleaning should be clearly explained. What software tools, mining methods and programming languages were used and how many iterations were necessary to see a clear trend or pattern in the current data under investigation? What was the size and nature of the cleaned data?
- In Predictive stage of BDA, specifically what statistical and other methods were utilized? What were the parameters and restrictions of the model? What were the advantages and limitations of the model? Report the results and sensitivity analysis, if any. How was the validation process conducted for testing to support the obtained results?
- In Prescriptive stage, if conducted, what optimization techniques were used? What were the advantages and limitations of the employed prescriptive methodologies?
- At how many of the three BDA stages various methods of visualizations (such as Tableau) were used?
- What were the list of all software, programming languages and IT tools that were used for each stage of the project?
- What about the feasibility for the scalability of the project? Up and down in data base size? Variability of data type (e.g., moving from text data to sensor data or the reverse)?
- If the research proposes a conceptual model, what are the implications if the model is indeed applied in practice? Any limitations?
- What about the required IT infrastructure to support the future similar research? What IT architectures should be pursued or avoided? On-premise or cloud technologies?
- What about using the cloud technology to satisfy the BDA needs in the conducted project? Pros and cons?
- What were the economic analysis and/or cost savings?

## **CONCLUSION**

According to our observations in the body of the literature and related industrial interviews, BDA research must expand in quantity, variety, and enhance in quality in order to have a positive impact on the operational, tactical and strategic decision making for manufacturing enterprises. Furthermore, companies must make an attempt for their technical BDA team to reasonably understand the related business processes. Conversely, the business management teams should be somewhat exposed to BDA concepts so that the two sectors of the enterprise can conduct the BDA projects in an iterative and consultative manner to effectively achieve the initial business proposition goals. This paper promotes a model to depict the integration of BDA and business teams for an iterative and integrative business problem solving.

Potential BDA research in various manufacturing enterprise echelons are numerous and deserve attention. Furthermore, due to the variety and complexity of BDA research possibilities, the outcomes of the undertaken projects should be disseminated in a reporting format that includes clear and transparent contents to facilitate the replication and application of the proposed methods in future research or industrial practices. This paper

offers suggestions for potential future BDA research areas in manufacturing enterprises and also includes a set of specific recommendations for BDA researchers to cover in the reporting and dissemination of their research results to assist and guide similar and complementary research in the future.

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# THE IMPACT OF ENTERPRISE RESOURCE PLANNING MATURITY AND SUPPLY CHAIN PERFORMANCE

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## Abstract

**Purpose of this paper:** Enterprise Resource Planning (ERP) systems are considered as a key to supply chain integration through information sharing and providing better visibility (Bartlett et al., 2007; Li et al., 2009; Kelle and Akbulut, 2005). It is argued, however, that there are different maturity stages in ERP implementation and ERP makes contribution to supply chain performance at a particular maturity stage (Holland and Light, 2001). This paper, therefore, aims at examining the impact of ERP maturity on supply chain performance.

**Design/methodology/approach:** This paper investigates the causal relationships between ERP implementation, ERP maturity and supply chain performance using a structural equation modelling (SEM). Data is collected from global firms that works in South Korea using questionnaire survey and 356 responses are obtained. Firstly supply chain performance is associated with ERP implementation, ERP maturity. Subsequently mediating effect of ERP maturity is tested through investigating direct and indirect impact between ERP implementation and performance.

**Findings:** It is found that ERP implementation factors (functionality, education and organisation) contribute to ERP maturity and ERP maturity has positive impact on supply chain performance. It is also suggested that ERP maturity has a mediating role indicating a certain level of ERP maturity is required for improving performance.

**Value:** ERP Maturity has not been considered in the literature. This paper may be the first attempt to associate ERP maturity with supply chain performance.

**Research limitations/implications (if applicable):** The contribution to the literature is that this paper empirically explains how the ERP implementation factors contribute to supply chain performance through ERP maturity.

**Practical implications (if applicable):** This paper provides managers and practitioners with implication that ERP systems should go through a certain level of maturity for success of ERP introduction resulting in performance improvement.

## 1. INTRODUCTION

Enterprise Resource Planning (ERP) systems are considered as a key to supply chain integration through information sharing and providing better visibility (Bartlett et al., 2007; Li et al., 2009; Kelle and Akbulut, 2005). Therefore firms have adopted ERP systems expecting enhanced transparency across supply chains and eventually improved performance of firms and supply chains (Holland et al., 2000). However there have failure cases of ERP implementation been reported in the literature (Ram et al., 2013) so researchers have paid much attention to success factors of ERP adoption and implementation for decades (Bingi et al., 1999; Hong and Kim, 2002; Motwani et al., 2005; Finney and Corbett, 2007; Ram et al., 2013).

It is argued, however, that ERP implementation efforts are managed differently and there are variance in ERP strategies, implementation and adaptation to firms' requirements (Holland and Light, 2000; Akkermans et al., 2003). Case studies on the impact of ERP on SCM demonstrates that possible contribution that ERP systems may make to SCM is limited depending on the extent to which ERP systems are adapted and customized to firms' business contexts and requirements (Forslund, 2010; Akkermans et al., 2003; Hong and Kim, 2002). ERP maturity concept is very useful to capture this variance in ERP implementation. It is suggested that there are different stages of maturity in ERP implementation in terms of strategic use of IT, organizational sophistication, penetration of the ERP system and so on (Holland and Light, 2000; Parthasarathy and Ramachandran, 2008). This argument demonstrates that ERP implementation factors work variably depending on ERP maturity stage of firms. However ERP maturity concept has not been



considered in ERP implementation and SCM literature. This paper, therefore, aims at examining the causal relationship between ERP implementation factors, ERP maturity and SCM performance. To this end, a research model associating ERP implementation factors and ERP maturity with SCM performance is developed through the review of the relevant literature and the model is examined using structural equation modelling (SEM) analysis. Data used for the analysis is collected from global companies that operate in South Korea.

The remaining of this paper is structured as follows. Section 2 reviews the literature relevant to ERP implementation factors, ERP maturity and SCM performance. Section 3 develops a research model based on the literature review and provides research methods and data collection process. Section 4 tests research hypotheses by examining the research model using SEM analysis. Section 5 undertake post-hoc analysis examining mediation role of ERP maturity in the research model. Section 6 provides research findings and conclusion.

## **2. THEORY AND CONCEPTS**

### **2.1. ERP implementation factors**

ERP systems are complex and require huge financial investments and organizational efforts for successful implementation (Davenport, 1998; Parthasarathy and Ramachandran, 2008; Grabski et al., 2011). While firms expect improvement of business performance through ERP implementation, there exist high risk of failure in implementing ERP systems (Davenport, 1998; Ram et al., 2013). Due to the risks and challenges in ERP implementation, the literature has discussed important factors of ERP implementation (Bingi et al., 1999; Hong and Kim, 2002; Finney and Corbett, 2007). The implementation factors can be categorised into three in this study.

#### ***ERP Functionality***

Functionality of ERP is considered as a primary factor of ERP implementation (Forslund, 2010). ERP typically consists of modules of master production schedules, materials requirements planning, inventory management and financial control (Helo and Szekely, 2005; Helo et al., 2008; Krajewski et al., 2007). Relevant data are entered, processed, monitored and reported in ERP systems (APICS, 2007). The data and information reported in ERP systems expected to be provided timely and sufficiently, and to be necessary and useful to users' demands (Umble et al., 2003). Functionality also is concerned about convenience of related tasks such as data entering, processing and reporting. In addition, data processing capabilities of ERP need to be able to adapt to individual users' needs or information strategies of firms (Holmberg, 2000). In this study, ERP Functionality is referred to as *the extent to which ERP systems are capable of managing information, making the information management process convenient and adapting to changing business environments*.

#### ***ERP Organization***

Organizational supports are indispensable to successful implementation of ERP (Finney and Corbett, 2007; Garcia-Sanche and Perez-Bernal, 2007). Umble et al. (2003) demonstrates that ERP teams in charge of implementation should be composed of high-quality, well-trained, sufficient workforce. Top management supports are definitely required because executive level initiative is critical when firms innovate existing business process (Nah and Delgado, 2006). Even after ERP implementation projects are completed, there should exist a team that in charge of ERP maintenance and repair and manuals and guidelines in preparation for emergent recovery of ERP systems (Dezdar and Sulaiman, 2009; Bingi et al., 1999). ERP organization in this study is concerned about *the extent to which firms provides organizational supports in implementation of ERP systems*.

#### ***ERP Education***

Education or training for employees or users is regarded as the most critical factor in ERP implementation (Ram et al., 2013; Umble et al., 2003). ERP implementation requires so much amount of knowledge that extensive training and education are necessary. It is also important that the knowledge necessary for ERP implementation should be internalized

because of the external nature of ERP systems (Melone, 1990; Ram et al., 2013). Kim and Kankanhalli (2009) demonstrate that proactive education and training for employees is critical to mitigate resistance of employees to new information technology. This study defines ERP Education as *the extent to which training and education are provided regularly in consideration of properties of users' tasks*.

## **2.2. ERP Maturity**

It has been suggested that there are different levels of maturity in ERP implementation (Holland et al., 2000; Parthasarathy and Ramachandran, 2008). Although ERP systems are considered as necessity of modern business for small and medium sized- as well as large enterprises, there are differences in how ERP systems are implemented in conjunction with other enterprise systems being adapted to different business contexts (Hong and Kim, 2002). Holland et al. (2000) suggested there are broadly three stages of maturity as a result of maturity assessment with interviews with 24 companies. Parthasarathy and Ramachandran (2008) highlighted that maturity concept is useful for ERP implementation team to assess maturity level and to develop complete solutions to firms requirements. Maturity of ERP systems can be assessed in terms of: how ERP systems are strategically considered important; how ERP systems fit with organizations; how much employees' accept or are satisfied about the functionality of ERP systems; and how well information is shared within firms. The literature suggests that ERP implementation factors may lead to the success of ERP implementation enabling firms to move onto further stages maturity. Therefore this study hypothesizes that ERP implementation factors contribute to ERP Maturity of firms as below.

*H1: ERP Functionality positively contribute to ERP Maturity*

*H2: ERP Organization positively contribute to ERP Maturity*

*H3: ERP Education positively contribute to ERP Maturity*

## **2.3. SCM performance**

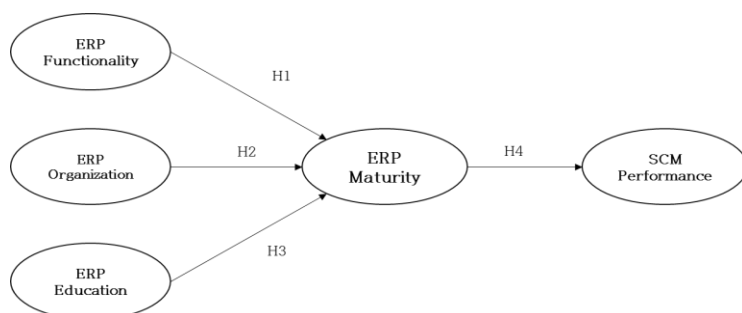
SCM is defined as "an integrative philosophy to manage the total flow of a distribution channel from the supplier to their ultimate user" (Cooper and Ellram, 1993). The components of SCM have been identified in the existing literature but generally include: information sharing across supply chains; Shared risks and rewards, integrated process, cooperation (Mentzer et al., 2001; Min et al., 2007; Lin et al., 2005; Li et al., 2006; Woo et al., 2011; Woo et al., 2013). SCM performance can be improved through better visibility supported by integrated IT systems such as ERP systems (Akkermans et al., 2003; Bartlett et al., 2007). Contribution of ERP to supply chain performance is generally accepted by the literature. However it is argued that the contribution of ERP to supply chain performance improvement is constrained by generic nature of ERP functionality and lack of flexibility to fast-changing supply chain requirements (Akkermans et al., 2003; Forslund, 2010). Therefore it is suggested that SCM performance is likely to be improved when ERP Maturity of firms is on the higher level ensuring flexibility, adaptability and organizational fit.

*H4: ERP Maturity positively contributed to SCM performance.*

## **3. RESEARCH MODEL AND METHODOLOGY**

Research model was developed through the literature review to examine the causal relationship between ERP implementation factors, ERP maturity and supply chain performance as shown in Figure 1. ERP implementation factors include ERP functionality, organization and education. The constructs in the model are rather abstract and are not directly measured. Therefore they are measured using observed variables that are measurement scales. The measurement items were developed based on the existing literature and are piloted by 10 practitioners to ensure contents validity as shown in Appendix 1.

### **Figure 1. Research model and hypotheses**



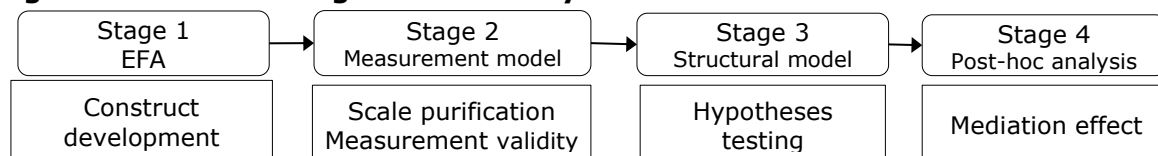
Data was collected from questionnaire survey which was administered in May and June 2016. 700 sets of questionnaire were distributed to sample companies which operate in South Korea. The number of responses was 364 and eight responses were excluded because there were missing answers. Thus response rate was 51% (356 out of 700). The profile of respondents are presented in Table 1.

**Table 1. Respondent profile**

Items	Categories	Frequency (%)
Sector	Manufacturing	157 (44%)
	Services, Retail and distribution	141 (40%)
	Others	58 (16%)
Annual sales (million USD)	50 above	102 (29%)
	10 - 50	110 (31%)
	5 - 10	76 (21%)
	5 below	68 (19%)
Position	CEO, Senior Manager	10 (3%)
	Middle Manager	286 (81%)
	Staff	60 (17%)

The collected data is analysed to examine the research model and hypotheses using structural equation modelling (SEM). SEM combines measurement verifying measurement validity and structural models examining hypothesized causal relationships (Hair et al., 2010). Four stages are taken in the analysis as shown in Figure 2. At the first stage, exploratory Factor Analysis (EFA) is conducted to make sure the constructs are extracted as designed in the measurement scales. At the second stage, measurement scales are purified and measurement validity is assessed. For scale purification, the collected data are subjected to Confirmatory Factor Analysis (CFA) with the maximum likelihood estimation (MLE). Measurement items with less than 0.4 or standardised residuals greater than 2.58 may be possible problematic items and can be considered for deletion (Min and Mentzer, 2004). In the measurement model phase, the five measurement constructs in the research model are examined in terms of measurement validity comprising unidimensionality, reliability, convergent validity and discriminant validity.

**Figure 2. Research stages in this study**



Unidimensionality is assessed using fit indices from various families of fit criteria: normalized fit chi-square statistics ( $X^2/df < 3.0$ ), comparative fit index ( $CFI > 0.9$ ), Tucker-Lewis index (TLI), and Root Mean Square Error of Approximation ( $RMSEA < 0.8$ ). For scale reliability, composite reliability ( $> 0.7$ ), average variance extracted (AVE) ( $> 0.5$ ) and Cronbach's alpha ( $> 0.7$ ) are assessed. Convergent validity is verified by determining whether each parameter estimate (standardised regression weights) on its posited

underlying construct is statistically significant (Anderson et al., 1987) and above at least 0.5. Discriminant validity is verified when the correlation between constructs is lower than 0.85; the AVE of each construct is higher than 0.5; and the AVE of each latent variable is higher than the squared inter-construct correlation associated with the corresponding constructs (Fornell and Larker, 1981; Hair et al., 2010). At the third stage, structural model is tested with causal paths hypothesized in Section 2. Overall model fit and structural coefficients are assessed. In addition, at the post-hoc analysis stage, both indirect and direct effects between ERP implementation factors and SCM performance are evaluated to examine mediating effect of ERM maturity. The results provides firms with implications on the role of ERP maturity when the firms introduce and implement ERP systems.

## 4. HYPOTHESES TESTING

### 4.1. Measurement model

Exploratory factor analysis (EFA) was undertaken and the result are presented in Appendix 2. It is shown that all the measurement items load on the corresponding constructs respectively and their loading factors are greater than 0.5. Table 2 shows the results of CFA results. It is hypothesized that each observed variables are associated with their constructs and each constructs are correlated.

**Table 2. Confirmatory Factor Analysis Results**

Construct	Observed variable	Load	t-value	SMC	CR	AVE	alpha
ERP functionality	FUNC1	0.829***	-	0.686	0.94	0.726	0.940
	FUNC2	0.858***	20.183	0.736			
	FUNC3	0.877***	20.914	0.769			
	FUNC4	0.871***	20.659	0.758			
	FUNC5	0.859***	20.202	0.737			
	FUNC6	0.819***	18.758				
ERP organization	ORG1	0.91***	-	0.828	0.945	0.743	0.945
	ORG2	0.918***	28.744	0.842			
	ORG3	0.855***	24.016	0.731			
	ORG4	0.857***	24.109	0.734			
	ORG5	0.81***	21.365	0.656			
	ORG6	0.817***	21.738	0.668			
ERP education	EDU1	0.837***	19.362	0.700	0.931	0.730	0.936
	EDU2	0.852***	19.905	0.725			
	EDU3	0.877***	20.869	0.768			
	EDU4	0.874***	20.760	0.763			
	EDU5	0.832***	-	0.692			
ERP maturity	MAT1	0.853***	-	0.728	0.916	0.687	0.941
	MAT4	0.812***	19.103	0.660			
	MAT5	0.828***	19.738	0.686			
	MAT6	0.852***	20.738	0.727			
	MAT7	0.799***	18.590	0.638			
ERP performance	PERP1	0.840***	-	0.703	0.922	0.666	0.922
	PERP2	0.830***	19.165	0.687			
	PERP3	0.831***	19.296	0.693			
	PERP4	0.817***	18.764	0.669			
	PERP5	0.763***	16.93	0.584			
	PERP6	0.813***	17.629	0.663			

CMIN/DF=2.848 CFI=0.935 IFI=0.935 TLI=0.928 RMSEA=0.072

The overall model fit was not sufficiently satisfactory but was acceptable with CMIN/DF=2.848 CFI=0.935 IFI=0.935 TLI=0.928 RMSEA=0.072. Unidimensionality is verified with the acceptable overall model fit. The values of construct reliability, AVEs and Chronbach's alpha of each constructs were above 0.7, 0.5 and 0.7 respectively which indicates scale reliability. In addition all the loadings on each constructs are reasonably high ranging from 0.763 to 0.918 and statistically significant at the 1% significance level, which indicates convergent validity. Discriminant validity was tested as shown in Table 3. The inter-construct correlations (ICC) associated between each constructs are lower than

0.85, the AVEs of each constructs are above 0.5. The AVEs of each constructs are mostly greater than the squared ICCs between associated constructs except for ERP maturity and SCM performance. However the difference is marginal so we move on to structural model.

**Table 3. Discriminant validity**

	FUNC	ORG	EDU	MAT	PERP
FUNC	<b>0.726</b>				
ORG	0.807 (0.651)	<b>0.743</b>			
EDU	0.799 (0.638)	0.722 (0.521)	<b>0.730</b>		
MAT	0.800 (0.64)	0.735 (0.540)	0.836 (0.698)	<b>0.687</b>	
PERP	0.726 (0.527)	0.696 (0.484)	0.757 (0.573)	0.845 (0.714)	<b>0.666</b>

Note: diagonal line: AVEs of each constructs. Under the diagonal line: the inter-construct correlations, Parentheses: the squared inter-construct correlations.

#### 4.2. Structural model

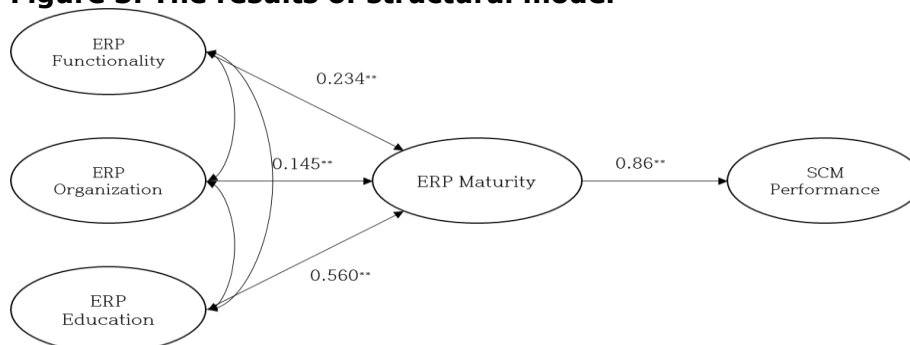
Four causal paths were hypothesized between ERP implementation factors (functionality, organization and education), ERP maturity and SCM performance. The hypotheses were examined in the structural model. Overall model fit of the structural model is almost the same as the measurement model: CMIN/DF=2.853 CFI=0.934 IFI=0.934 TLI=0.928 RMSEA=0.072. Given the acceptable model fit, the individual paths were evaluated as shown in Table 4 and Figure 3. All the paths between ERP implementation factors and ERP maturity were statistically significant with coefficient of 0.271 ( $t=3.785$ ,  $p<0.001$ ), 0.159 ( $t=2.693$ ,  $p=0.007$ ) and 0.515 ( $t=8.154$ ,  $p<0.001$ ) respectively. The Maturity-Performance path was also significant with coefficient of 0.860 ( $t=16.715$ ,  $p<0.001$ ). Among the significant paths, the loading weight of the path Education-Maturity was relatively greater than those of the Functionality-Maturity and Organization-Maturity paths.

**Table 4. The results of structural model**

Hypothesis	Path	Weight	t-stats	p-value
H1	Functionality→ Maturity	0.271	3.785	<0.001
H2	Organization→ Maturity	0.159	2.693	0.007
H3	Education→ Maturity	0.515	8.154	< 0.001
H4	Maturity→ Performance	0.860	16.715	< 0.001

CMIN/DF=2.853 CFI=0.934 IFI=0.934 TLI=0.928 RMSEA=0.072

**Figure 3. The results of structural model**



#### 5. Mediation role of ERP maturity

Direct paths from ERP functionality, ERP organization and ERP education to SCM performance to investigate ERP implementation factors only can contribute to SCM

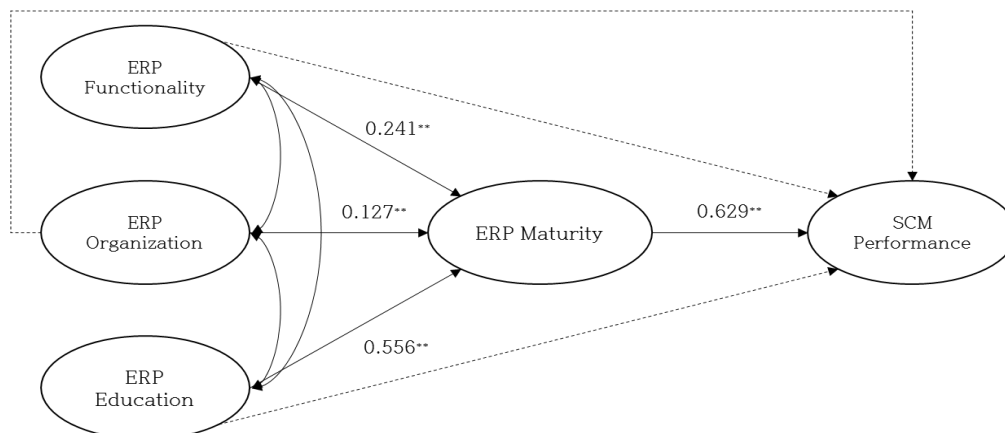
performance without mediation role of ERP maturity. If the direct paths are significant while indirect paths from ERP implementation factors via ERP maturity to SCM performance are not significant, then there is no mediation effect of ERP maturity. On the contrary, if the indirect paths are only significant, there is full mediation effect.

Direct and indirect paths were examined as shown in Table 5 and Figure 4. Overall model fit of the structural model is almost the same as the measurement model: CMIM/DF=3.04, CFI=0.93, IFI=0.93, TLI=0.92 and RMSEA=0.076. All the indirect paths (H1-H4) were statistically significant at the 1% significant level whereas the direct paths were not significant which indicates full mediation effect of ERP maturity.

**Table 5. Direct and indirect effects**

Hypothesis	Path	Weight	t-stats	p-value
H1	Functionality→ Maturity	0.277	3.691	<0.001
H2	Organization→ Maturity	0.141	2.281	0.023
H3	Education→ Maturity	0.513	7.788	< 0.001
H4	Maturity→ Performance	0.640	7.383	< 0.001
Direct path	Functionality→Performance	0.019	0.232	0.816
	Organization→Performance	0.126	1.892	0.052
	Education→Performance	0.116	1.678	0.140
CMIN/DF=2.848, IFI=0.935, CFI=0.935, TLI=0.928, RMSEA=0.072				

**Figure 4. Mediation effect of ERP maturity**



Note: Bold arrows represent significant path and dotted arrows represent paths that are not significant

## 6. Research findings and conclusion

This paper examined the causal relationship between ERP implementation factors, ERP maturity and SCM performance. Data were collected through questionnaire survey with 356 respondents working in global companies in South Korea. The results from the empirical analyses suggest that the respondents perceive that ERP Functionality, ERP Organization and ERP Education positively contribute to ERP maturity. It is suggested that the functions of ERP should be better aligned with users' need of information and information management strategies of firms so that firms can move to matured stage of ERP usage. The information provided and generated from ERP systems should be both necessary and useful and be provided timely to users' demand. It is also suggest that firms that have better organizational supports such as dedicated team to manage ERP systems, Top-management support and sufficient workforce are more likely to utilize ERP systems

in association with the overall management such as performance management and change management through better information sharing within firms. However the results highlight the importance of education with the relatively greater loading factor (0.515) than other loadings (0.271 and 0.159 respectively). Education for ERP systems and usage need to be regularly educated and reasonable resources should be allocated to the education function. It is suggested that education and training on ERP systems need to be coherently designed to users' tasks and task transition.

The role of ERP maturity was investigated through the structural model and post-hoc analysis. It was shown that ERP Maturity positively contributes to SCM performance. The mediation effect analysis suggest that only ERP implementation is not likely to improve SCM performance but should be substantially utilised by firms. In other words, it is required for SCM performance improvement through ERP implementation that: the users are satisfied with the information produced by ERP systems; ERP systems are substantially used in the process of performance measurement and change management; and information management is more efficient than before the introduction of ERP systems.

This paper makes substantial contribution to the literature. The previous literature investigated the impact of ERP implementation on firm performance and also suggested different levels of ERP maturity. However these topics have been addressed separately, which is a significant research gap in the ERP and SCM research. This study successfully filled the research gap by combining these issues in a research model and examining association between the ERP implementation, ERP maturity and SCM performance. It should be noted that this study may be the first examination on the role of ERP maturity on the causal paths that are important concerns of firms investing hugely on ERP systems. There are also limitation of this study. Moderating effects can be investigated through multi-group SEM analysis since the relationships can be differently applied depending on business environments and practices by different industrial sectors, firm culture and geographical regions. Future research therefore is required to broaden sample groups and examine the research model in a more general research settings.

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## Appendix 1

### Constructs and measurement scales

Constructs	Measurement items	Literature
ERP Functionality	Timely provision of information (FUNC1) Convenience of work (FUNC2) Abundance of information provided (FUNC3) Usefulness of information generated (FUNC4) Necessity of information provided (FUNC5) Adaptation of information strategies to business environments (FUNC6)	Klaus and Blanton (2010); Nah et al. (2003); Melone (1990)
ERP Organization	Existence of organization in charge of ERP information management (ORG1) Existence of organization in charge of ERP system (ORG2) Existence of organization in charge of ERP maintenance and repair (ORG3) Existence of guidelines in preparation for emergent recovery of ERP system (ORG4) Top management support for ERP management (ORG5) Sufficient workforce for implementation (ORG6)	Lee (2001); Somerand Nelson(2003); Bingietal.,(1999)
ERP Education	Regularity of education (EDU1) Resources for ERP education (EDU2) Provision of training for task changes (EDU3) Provision of training for train parallel (EDU4) Existence of manuals for ERP education (EDU5)	Lee (2001); Garcia-Sanche&Perez-Bernal(2007); Bingietal.,(1999)
ERP Maturity	Satisfaction on information from ERP (MAT1) Performance management through ERP (MAT2) Continuous change management (MAT3) Improvement of information efficiency through ERP (MAT4) Information sharing within your firm (MAT5)	Christopher et al(2000); Benbasat et al(1980),
SCM Performance	Information sharing in SC (PERP1) Shared risks and rewards (PERP2) Collaboration in SC (PERP3) Integration of core process (PERP4) Cost reduction through functional adjustment in SC (PERP5) Improved customer values and satisfaction (PERP6)	Ponomarov& Holcomb (2009); Bartlett et al. (2007); Fredericks(2005); Sanders & Premus(2002); Cooperetal.(1997)

## Appendix 2. Exploratory Factor Analysis Results

Construct	Observed variable	Component		
ERP functionality	FUNC1	0.737		
	FUNC2	0.734		
	FUNC3	0.731		
	FUNC4	0.717		
	FUNC5	0.620		
	FUNC6	0.575		
ERP organization	ORG1	0.805		
	ORG2	0.769		
	ORG3	0.768		
	ORG4	0.742		
	ORG5	0.674		
	ORG6	0.666		
ERP education	EDU1		0.768	
	EDU2		0.707	
	EDU3		0.704	
	EDU4		0.698	
	EDU5		0.625	
	EDU6		0.532	
ERP maturity	MAT1			0.726
	MAT2			0.723
	MAT3			0.702
	MAT4			0.649
	MAT5			0.64
ERP performance	PERP1			0.737
	PERP2			0.734
	PERP3			0.731
	PERP4			0.717
	PERP5			0.620
	PERP6			0.575
KMO=0.966, Chi-square=11192.721 (df=465, p<0.0001)				

# **PROCESS RE-USE IN LOGISTICS AND SUPPLY CHAIN MANAGEMENT**

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## **MOTIVATION AND PROBLEM STATEMENT**

Supply chain executives strive to gain a competitive edge over their rivals by achieving business process and operational excellence. By using information models, an attempt is made to create manageable artifacts with which the inherent complexity of [supply chain] processes becomes controllable (Thomas, 2005). This is why many organizations commit significant resources to process modeling and process management. Yet, many constructed models and even entire process model collections fall into disuse, which means that investments in process modeling are at risk of being lost (Nolte et al., 2016). Furthermore, many organizations lack process management and modeling capabilities which sometimes results in newly created models to be either ineffective, incomplete or defective in nature.

In order to employ resources more efficiently, organizations can promote the systematic use of existing process models and known business process practices as points of reference and blueprints for the development of new, problem-specific application models. However, in order to re-use existing process models and concepts in an effective and efficient manner, organizations as well as their supply chain partners must be able to successfully identify internally and externally available information models and processes. In addition, they also have to be capable and willing to assimilate, transform, and apply this knowledge within their own companies and supply chains.

On the one hand, numerous supply chain-related papers discuss process management issues. Yet, few emphasize and scrutinize the modeling process from an organizational development viewpoint. On the other hand, traditional work in the fields of business informatics and information systems often mainly focuses on technical aspects of reference process modeling and process re-use. This project aims at bridging current research gaps by providing insights into the process of systematically re-using existing process models and concepts in the supply chain domain. The authors particularly analyze process re-use from an organizational learning and knowledge management perspective.

## **RESEARCH DESIGN AND METHODOLOGY**

This study systematically analyzes re-use of process-based models in logistics and supply chain management on a more strategic level. In a first step, concepts promoting and enabling process re-use were identified based on a literature and document review. The findings were further developed and explicated by means of qualitative expert interviews with supply chain managers representing three distinctive industries (automotive, chemical, semiconductor). All approaches were then categorized and evaluated based on theory of knowledge. In this paper, a preliminary overview and theoretical analysis of process re-use in supply chain management is presented.

## SUPPLY CHAIN MANAGEMENT AS PROCESS MANAGEMENT

Corporate enterprises are increasingly confronted with ongoing globalization of markets, pressure caused by continuous innovation, and ever more demanding customers. As a result, they have to supply a growing number of products with features more and more tailored to consumers' individual requirements. This applies to both, product characteristics as well as to support services (Perona and Miragliotta, 2004). These developments and the trend of manufacturing firms to further concentrate on their core competencies and to outsource major parts of their activities gave rise to fragmented and complex global supply chains as the dominant logic of doing business in today's corporate environment. In a marketplace where success is increasingly determined by the performance of entire supply chains rather than by individual enterprises (Kaluza et al., 2006), an efficient management of them is of utmost importance. In this sense, supply chain management can be understood as 'a process-orientated management concept, including all flows of goods (raw materials, components, semi-finished and finished goods), services, information, and funds, as well as contractual and social relationships along the supply chain from the initial supplier of raw materials to the final customer with the goal of integrating all value-adding processes and subsequently achieving enhanced competitiveness of all actors along the supply chain' (Kummer and Groschopf, 2013). Lambert et al. (1998) proposed a framework composed of eight cross-functional and cross-firm business processes (cf. Figure 1) describing the overall supply chain process. It consists of (i) customer relationship management, (ii) customer service management, (iii) demand management, (iv) order fulfillment, (v) manufacturing flow management, (vi) procurement, (vii) product development and commercialization, and (viii) returns management (Lambert et al., 1998; Croxton et al. 2001).

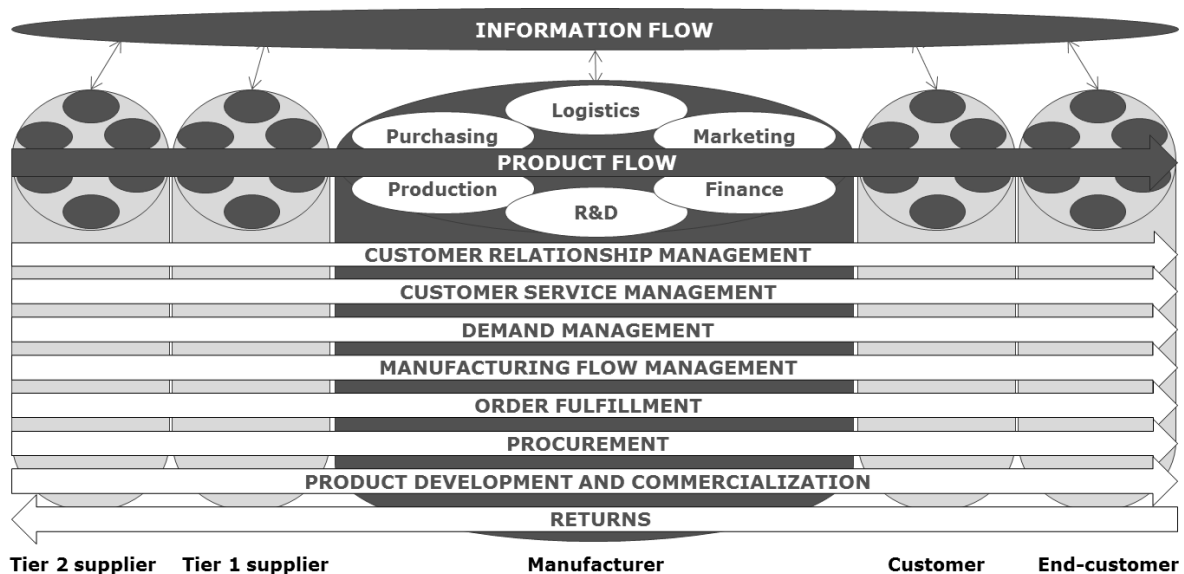


Figure 1: Supply chain process integration (Lambert et al., 1998; Croxton et al., 2001)

Systematically implementing these cross-functional processes within an organization as well as ensuring integration with key members of the supply chain constitute critical

success factors of supply chain management. Furthermore, a standardization of business processes across different organizations ensures that supply chain members can use a 'common language' and can subsequently link-up their companies' processes with other actors of the supply chain. What is more, achieving supply chain process excellence can give companies a competitive edge over rival firms. In addition, new or improved process designs can also be used as a means of innovation and can thereby support organizational development on a more strategic level.

## **PROCESS RE-USE AND PROCESS KNOWLEDGE SOURCING**

### **Process knowledge re-use**

In order to efficiently and effectively design, execute and control supply chain processes, managers generally have two options. On the one hand, they can model a new supply chain process from scratch without considering already available solutions. Alternatively, existing process knowledge can be systematically re-used. Knowledge re-use can be described as the process by which previously created knowledge is repurposed, modified, and recombined (Kyriakou et al., 2017; Alavi and Leidner 2001; Markus 2001). In this respect, according to Majchrzak et al. (2004), two general categories of re-use purposes can be distinguished.

- Re-use for replication: This is a specific form of knowledge acquisition: for a particular managerial problem, knowledge is re-used to solve that problem. No broader integration is needed, and there is no or little novelty.
- Re-use for innovation: In this case, the intention is to integrate new knowledge with other knowledge resulting in novelty. For example, a company might decide only to replicate certain parts of an existing process model and to re-specify and further develop the remaining aspects.

When processes are re-used, a distinction must be made between the developer (supplier) of the reference process and the re-use efforts made by an implementing organization (user). The developer or supplier of an information model can already anticipate prospective re-use scenarios and can purposefully construct the model as a so-called reference model. This procedure can be termed as 'design for re-use'. Thereby, an attempt is made to construct a general model which can theoretically be applied to a category of applications rather than to a narrowly specified instance. It is a conceptual framework that can be used as a blueprint and can be progressively adapted to the requirements of a particular company (Fettke et al., 2006; Shtub and Karni, 2009). Yet, this does not necessarily mean that re-use will take place in practice. Hence, such models only constitute declared reference models (Thomas, 2005).

On the other hand, from the user's perspective, any existing process or process model – regardless of whether it had been declared as a reference – could theoretically be used as a blueprint. Whenever existing processes or models are used as a source of reference, 'design with re-use' is carried out. Users require reference models to ensure sufficient quality of the transferred know-how and are more likely to choose models which provide the best fit to their individual requirements (Becker et al., 2007).

In this study, following the argumentation of Thomas (2005), all models which are actually re-used (and thereby are accepted) by practitioners are considered to be reference models. In supply chain management, the Supply Chain Operations Reference (SCOR) Model developed by the Supply Chain Council meets both criteria and therefore is declared as well as an accepted reference model. However, this broad definition is a particular challenge for the re-using organization. While declared reference models are often openly communicated as blueprints and are constructed in a way which facilitates design for re-

use, identifying and using non-declared best practices is a much more complex task.

### Process knowledge sourcing

In the most general sense, process models or best practices for re-use can be either found internally or externally. On the one hand, internally available process knowledge consists of knowledge that is already available within the re-using organization, e.g. in another business unit or subsidiary. On the other hand, external knowledge has to be acquired from sources outside of the company. In order to successfully source external supply chain process knowledge, companies can follow the 5-phase approach outlined in Figure 2.

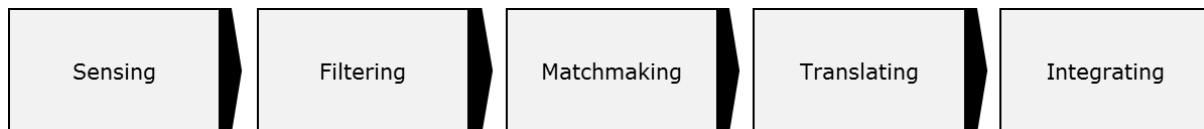


Figure 2: Supply chain process knowledge sourcing

In a first step, the company has to sense its business environment for best practices and potentially useful process models. This includes an analysis of publically available reference process collections, process documentations, as well as screening the processes used by partners and competitors or even by companies in other (e.g. more innovative) industries. Sensing units must become the 'eyes and ears' of the company's supply chain department. Filtering then describes efforts made by the re-using organization to identify all processes meeting two key requirements. On the one hand, they have to be relevant to current or potential future needs of the organization and, in addition, the process implementation capabilities of the firm have to be sufficient to allow for conducting design with re-use based on these process models. In the subsequent matchmaking phase, the identified reference models are then linked with actual internal process development or process change requirements. In a next step, the blueprint must be translated to be used in the new context within the application domain. This translating phase must be emphasized since it constitutes a crucial, gap-bridging activity. Companies can use a set of re-use techniques from reference modeling to perform this task (adapted and extended from vom Brocke, 2007; Rehse and Fettke, 2017):

- Duplication: A process-based model or concept can be duplicated and is re-used without any changes to be made.
- Configuration: Model parts are adopted according to the parametrization of the process domain (e.g. product specific process configuration). Individual model parts are selected and derived from a predefined, configurable component.
- Instantiation: General domain aspects are designed as a framework providing generic placeholders for plugging in model parts, considering the specific requirements of the application domain.
- Specialization: Entire contents of a generic model are adopted into a specific model, allowing individual modification and extension. The resulting model contains all contents of the individual model.
- Aggregation: Contents are extracted from various part models which are synthesized and adopted into the new model. The resulting model is composed of the individual model parts.
- Analogy: Seemingly similar solutions are employed in a creative way to address new problems (e.g. in another industry). The original model is used as orientation and general guideline for the design of the new model, such that they are perceived to be coinciding in certain [relevant] aspects.
- New model: An entirely new model is designed without employing any existing concepts. The new solution has to be designed from scratch.

Following this 5-phase approach results in the development and deployment of a domain-specific process model that can be integrated into the company's process landscape.

### **Knowledge sourcing capability**

Although the outlined approach appears to be straightforward, successful process re-use must be identified as a major challenge for many supply chain practitioners. Interview partners in all analyzed industries characterized the knowledge sourcing capabilities of their companies as either nonexistent or insufficient.

Nevertheless, in an increasingly complex business environment it can be claimed that knowledge sourcing will become a key capability of companies since it allows them to tap into new ideas and best practices from beyond their traditional boundaries (Katila and Ahuja, 2002; Laursen and Salter, 2006; Monteiro and Birkinshaw, 2016; Rosenkopf and Nerkar, 2001). This is particularly the case for companies embedded in global supply chains with multifaceted and interrelated processes. However, gaining access to external knowledge is extremely difficult because of major institutional, technological, and geographical boundaries that have to be crossed. What is more, external knowledge acquisition and integration requires a set of skills which differs from capabilities enabling internal best practice and knowledge transfer (Monteiro and Birkinshaw, 2016; Hansen, 1999).

One way to determine the general capability of a firm to successfully re-use supply chain processes is by analyzing its absorptive capacity. This measure characterizes a firm's ability to identify, assimilate, transform, and apply valuable external knowledge (Cohen and Levinthal, 1990). Absorptive capacity can be understood as one of the company's dynamic capabilities, which represent 'the ability to integrate, build, and reconfigure existing resources to renew functional competencies that adapt to rapidly changing environments' (Teece et al., 1997). The dynamic capabilities view is an extension of the resource based view (Makadok, 2001) which postulates that the basis for the competitive advantage of a firm lies primarily in the application of a bundle of valuable tangible or intangible resources at the firm's disposal (Barney, 1991; Penrose, 1959; Wernerfelt, 1995).

## **CONCLUSION AND PERSPECTIVES**

### **Discussion and managerial implications**

This paper analyzed the concept of process re-use in supply chain management. After characterizing the supply chain process as a composition of eight cross-functional and cross-firm business processes, re-use was introduced as an approach to systematically repurpose, modify, and recombine previous process knowledge. Re-using proven supply chain processes can help companies to achieve operational excellence and might even be used as a means for supporting process innovation.

However, the concept of re-use is dependent on a firm's capability to identify, assimilate, transform, and apply valuable external knowledge. In order to fully utilize their process re-use potential and to successfully manage knowledge sourcing activities in supply chain management, companies have to ensure sufficiently high levels of absorptive capacity within their organizations and within their supply chains. Therefore, it is imperative for firms to strategically build such capabilities.

### **Further research**

It is undisputed that business process modeling has received a lot of attention from practitioners as well as researchers. This is underpinned by numerous scientific publications as well as by significant investments made into process modeling and process management by organizations.

While previous research has extensively discussed modeling for re-use (most importantly reference model construction), design with re-use still seems to be an underdeveloped area. Furthermore, with the exception of studies specifically discussing the SCOR model, a critical reflection of conceptual modeling practices is underrepresented in the field of supply chain management. Moreover, existing work often focuses on technical aspects or particular practitioner problems and therefore sometimes is not sufficiently rooted in theory. Borrowing concepts and theories from different fields (including knowledge management and strategic management) could help to bridge this gap.

Based on these findings, the authors identify two potential areas for future research. On the one hand, there is a need for more research about reference model construction in supply chain management. On the other hand, supply chain process re-use should be further investigated from the user's perspective. In addition to studying specific techniques and concepts facilitating process re-use, factors determining and influencing a firm's absorptive capacity should be further investigated in order to better capture phenomena stemming from the boundary-spanning and cross-functional nature of supply chain management processes.

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## **Session 2: Supply Chain Services**

# SEAMLESS LOGISTICS SYSTEMS OF AUTOMOBILE PARTS BETWEEN JAPAN AND KOREA

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## ABSTRACT

### Purpose

Japanese automobile manufacturers have introduced seamless logistics systems through mutual use of chassis making use of ferries or RORO (Roll On Roll Off) vessels between Korea and Japan recently. This system is a good case in international logistics systems based on the Just in Time (JIT) principle. The purpose of this paper is to analyse their current situations and issues and to explore possibilities of their developments.

### Design

The present situations in production and procurement of Japanese automobile industry in Kyushu and the trend of Japan-Korea automobile parts trade is analysed through existing literatures and statistical survey. Then, the actual situations of the seamless logistics systems are discussed based on the interview on automobile manufacturers and logistics companies and literature survey.

### Findings

As a part of global supply chain management, automobile manufacturers have constructed the seamless logistics for an important means of reducing inventory and logistics costs. Logistics companies are proposing and operating efficient logistics systems as 3PL (Third Party Logistics) providers. In international logistics where regulatory and institutional differs substantially between countries, policy harmonization through the framework of the Japan-Korea Logistics Ministers' Meeting and trade facilitation by the AEO (Authorised Economic Operator) system and so on are important.

### Value

To establish international seamless logistics systems based on JIT principle, the importance of cooperation between shippers and logistics companies as well as policy harmonization is shown. The importance of expanding the seamless logistics systems into Northeast Asia region is pointed out. This paper provides unique case study for global SCM and logistics literature.

## INTRODUCTION

To cope with global competition, Japanese automobile manufacturers have developed sophisticated global procurement network. In the northern part of Kyushu Island where large-scale assembly factories are located, they have increased the procurement of Asian parts, as the quality of them has improved and the cost of them has become cheaper due to the high appreciation of yen. They have introduced seamless logistics systems through mutual passage of chassis making use of vessels between Busan, Korea and Kyushu. The seamless logistics systems play an important role as "conveyors beyond the sea".

After reviewing relevant literature, production and procurement situations of Japanese automobile industry located in Kyushu are grasped through existing literature and statistics. Then, the scale and trend of Japan-Korea automobile parts trade are analysed based on Japanese and Korean trade statistics. After that, the concrete supply chain

operations are clarified by interview surveys on automobile manufacturers and logistics companies. Lastly, concluding remarks follows.

## **A REVIEW OF RELEVANT LITERATURE**

Among the many literature on the procurement of Japanese automobile manufacturers, Nemoto and Hashimoto (2010) focused logistics systems, which stressed that the procurement logistics of Japanese manufactures were based on JIT principle from the survey on some cases in China and ASEAN. Hayashi and Nemoto (2010) showed Toyota utilized the Yangtze River transport as an important part of procurement logistics systems in inland China. Nemoto, Hayashi and Hashimoto (2010) clarified that Japanese automobile manufacturers introduced milk-run procurement system in Thailand. These literature showed the principles of procurement by Japanese automobile manufactures and pointed out that they tried to adopt the principle even in foreign countries.

As for the literature on automobile industry in Kyushu, Kyushu Bureau of Economy, Trade and Industry (2013) and other reports by local governments showed the overview and many statistics on it. Ishiro and Mokudai (2013) pointed out some issues on the Kyushu automobile industry. Kodama (2013) and Harada (2013) discussed logistics and SCM strategy of Japanese automobile manufactures in Kyushu. Emoto and Han (2015) pointed out the structural changes of Japan-Korea automobile parts trade. Emoto (2013) also discussed the changes of trade network and organizational collaboration between automobile manufacturers. These literatures stressed that Korean parts had been getting more import for automobile manufacturers in Kyushu to be more competitive.

Fujiwara (2014) showed the progress in seamless logistics by RORO shipping in East Asia including Korea and Japan. Fujiwara and Emoto (2013) proposed that seamless logistics should play an important role in growth strategy in Kyushu. Wi (2015) also pointed out that seamless logistics should contribute economic development in Northeast Asia.

## **AUTOMOBILE MANUFACTURERS IN KYUSHU**

### **Production**

Kyushu Island locates in southwestern part of Japan, and boasts to be one of the automobile industry clusters. Automobile industry accumulates on the northern part of Kyushu, and currently four finished car manufacturers operate seven factories. The number of vehicles assembled in Kyushu had reached 1.3 million units in 2014, accounting for 13.3% of the total units assembled in Japan.

Nissan has positioned each factory in Japan as a global mother plant and is trying to maintain one million vehicles of domestic assembly. Among others, the Nissan Motor Kyushu Plant is positioned as a low-cost leader for mass-production models and assembles about half of the Nissan's domestic vehicles. In addition, at the latest Nissan Kyushu Plant, passenger cars of monocoque structure and SUVs (sports multipurpose vehicle) of frame structure are assembled.

### **Procurement**

As the scale of production in Kyushu expands, the local procurement rate has been increasing due to the growth of local parts suppliers. However, compared with other clusters such as in Kanto or Chukyo, the local procurement rate in Kyushu is still low. Especially the procurement rate for important parts such as engines, engine parts, drive transmission and control equipment parts are low.

Finished car manufacturers are trying to improve their local procurement rates to reduce costs. Nissan Motor Kyushu regards the local procurement rates as the proportion of parts costs purchased from suppliers in Kyushu region and LCC (Low Cost Country) to the total purchase costs. In the case of Note, which is the largest production model among all Nissan models, the local procurement rate is 85%. In the case of X-TRAIL,

which is also produced in the USA and Korea, the local procurement rate has increased to 94%.

### **Overseas procurement**

Along with the progress of high appreciation of yen and the development of overseas automotive parts industry, Japanese automobile manufactures try to procure more overseas parts that are relatively inexpensive and of high quality. Nissan Motor Kyushu, as a cost leader in Nissan group, has been increasing imports from LCC as well as procurement within Kyushu.

Nissan Motor Kyushu and other Japanese manufacturers are also trying to procure more overseas parts. Furthermore, overseas procurement has been getting popular among parts suppliers such as tier one. According to the questionnaire survey by Kyushu Bureau of Economy, Trade and Industry (2013), 17% of tier one suppliers located in Kyushu were procuring from overseas and 31% of them answered that they would increase procurement from overseas.

## **AUTOMOBILE PARTS TRADE IN KYUSHU**

### **Recent trends in trade**

Japanese automobile manufacturers' movement for expanding overseas procurement in the previous chapter is confirmed by trade statistics of automobile parts as follows. Looking at the trend of automobile parts in Kyushu (including Shimonoseki Port, hereinafter the same), the import value has increased sharply, while the export value is stagnant. The import value of automobile parts in 2015 was about 161 billion yen, about 2.3 times of 69 billion yen in 2010.

As for the origin country of import, Asian countries such as China, Korea and Thailand remarkably increased the value of import, and the composition ratios in 2015 were 42%, 19% and 12%, respectively. The supply chain of automobile parts has been expanding to Asia mainly in the neighbour countries. Kyushu has higher proportion of procurement from Korea and China, which are close to Kyushu.

### **Automobile parts trade with Korea**

In automobile parts trade between Kyushu and Korea, imports from Korea have been growing rapidly. Especially since Nissan Motor Kyushu established a seamless logistics system with Korea, the amount of imports has been increasing.

As for the ports used for importing parts from Korea, almost all of them are through Hakata Port, Moji port, and Shimonoseki Port, where regular vessels are calling. The value of imports through Shimonoseki Port in 2013 increased nearly four times of the one in the previous year, when the chassis with both Japanese and Korean plates have introduced through Busan Port and Shimonoseki Port.

## **PROCUREMENT STRATEGIES OF AUTOMOBILE MANUFACTURERS**

### **Procurement strategy of Nissan Motor**

Automobile manufacturers think highly of logistics functions to procure more than thirty thousand kinds of parts efficiently. Renault-Nissan Group has established a joint purchasing organization, Renault-Nissan Purchasing Organization (RNPO) to purchase their parts. Thus, RNPO decides the suppliers for Nissan Motor Kyushu.

In 2012, Nissan has introduced CMF (Common Module Family) as a vehicle design technology for the new generation. Nissan aims at simplifying production process and utilizing economy of scale by CMF. Nissan tries to raise the CMF rate from 12% in 2013 to 58% in 2016. Furthermore, Nissan and Renault has a plan to expand CMF jointly from 7% in 2012 to more than 50% in the future.

As a comprehensive cost reduction measure, RNPO has lead the reduction of total delivered cost (TdC). TdC is "comprehensive cost competitiveness enhancement activities including not only parts procurement cost but also vehicle assembly cost and logistics cost". TdC measures include LCC conversion, localization, decrease of tariffs and customs duties, and so on. Logistics measures include route review, inventory reduction, packaging improvement, physical distribution quality improvement, and so on.

### **Strategy in Kyushu**

At Nissan, overseas production outpaced domestic production in the early 21st century, and Nissan Production Method, NPW (Nissan Production Way) began to expand globally. To compete for quality improvement and cost reduction among factories in the group, Nissan started internal benchmarking to compare the performance globally.

Nissan Motor Kyushu Plant (before spun off at that time) was lost to the Thai factory in the competition for the production base of the new compact car, March. Nissan Motor Kyushu Plant established a Kyushu Victory Strategy to cope with "5 heavy disadvantages (high yen appreciation, high corporate tax, delay in trade liberalization, labour regulation, and global warming countermeasures)" in 2010.

The pillar of Kyushu Victory Strategy was to speed up decision making, to reduce costs of purchased items, to reduce distribution cost, and to reduce internal production cost. By the end of FY2012, Nissan aimed to reduce total cost per vehicle by 25% over three years and to have competitiveness equivalent to overseas production.

### **Supply Chain of Nissan Motor Kyushu**

One of the important issues in the Kyushu Victory Strategy was SCM (Supply Chain Management) which took advantage of the geopolitical superiority. The Kyushu factory locates in the centre of East Asia. The distance to the Busan Factory of Renault Samsung, a brother company, is only about 200km. In Korea, there are also large number of parts supplier for Korean automobile manufacturers, Hyundai Motor and Kia Motor. The distance to Shanghai, where there are many competitive parts suppliers, is also 1,100 km, which is nearly equal to the distance to Yokosuka Port. Nissan Motor Kyushu procures parts 4 times a week by coastal shipping from Yokosuka Port. The supply chain connected to Korea and China began full-scale for the new Caravan and Note in 2012.

Nissan Motor Kyushu imports parts from LCCs other than Korea in large lots due to low frequency of vessels, and stock them once in the warehouse. Unpacked at the warehouse, they convert parts into packaging for assembling in the factory. They deliver these parts to Parts Logistics Centre (PLC) adjacent to the factory, then sort them in the order of assembly, and put them assembly lines.

As for the procurement in Kyushu Island, Nissan requests suppliers to locate near the assembly factory, that is, on site (in the factory building), in site (in the factory premises), near site (near factory such as supplier park). These suppliers deliver their parts in the order of the assembly line synchronized with the assembly speed.

## **JAPAN-KOREA SEAMLESS LOGISTICS**

### **Introduction of seamless logistics system**

For SCM to make full use of geopolitical superiority, an efficient logistics system is necessary. It takes about only half a day to transport parts from Busan Port to Kyushu about 200km by vessels. However, in conventional container transport, various procedures such as container transfer between trucks and vessels at ports and inspection and customs clearance of cargo and transport equipment are required. In addition, it is necessary to provide robust export packaging so that it can withstand the shock of LOLO (Lift On Lift Off) handling by large cargo handling equipment such as gantry cranes.

During international container transport as described above, there are various joints (seams) that divide continuous logistics processes, so it took 40 days for lead time to deliver to an assembly factory since placing orders to suppliers in Korea. As a result, the parts stock reached 25 days' worth.

Nissan Motor started to study the import scheme by the RORO handling method in 2009 and applied Korean government for the permission to run Japanese chassis in Korea in 2012. After the pilot project agreement by the Japan-China-Korea Logistics Minister Meeting in the same year, Nissan started using the 4 chassis and 6 side open containers. In 2013, the seamless logistics system began full-scale operation by the chassis with the double Japan and Korea number plates.

By introducing a chassis that can run continuously between Japan and Korea, it is possible to shorten the transfer time at the ports. Nissan Motor Kyushu Plant orders certain amount of parts to Korean suppliers and then parts are loaded on the chassis. The chassis are towed to Pusan Port, loaded on a ferry, unloaded at Shimonoseki Port, and delivered to the Nissan Motor Kyushu Plant. In this RORO system with a small shock when loading and unloading, a robust export packing is unnecessary. Furthermore, it is possible to deliver parts directly the assemble line by using returnable containers or equipment like domestic transport. This eliminates the packing process and reduces packaging materials.

Import procedures have also become seamless. As Nissan Motor was accredited as an AEO (Authorized Economic Operator) importer, the examination and inspection at the time of import declaration was eliminated and the pickup of cargo was speeded up. It became possible to simplify tax exemption at the time of importing and reexporting of returnable containers made in Korea.

### **Chassis and containers for seamless logistics**

Mutual chassis transit between Japan and Korea was implemented based on applications from Nippon Express (Japanese logistics company) and Chunil Cargo Transportation (Korean logistics company). Nippon Express has provided a variety of logistics services as a comprehensive 3PL (third party logistics) operator. For the automobile industry, it provides 3PL services such as milk run collection, mixed loading and synchronized delivery of parts not only in Japan but also in China, Thailand, India, Mexico and so on.

Nissan Motor made a bid for the seamless logistics, and Nippon Express and Chunil won the contract with Nissan. Chunil operates cross-dock operation with milk run in Korea, and Nippon Express operates international and Japanese domestic operation and manage overall operations. 8 wing chassis with double plates and 20 wing chassis with Japanese single plate were used between Busan and Shimonoseki port in 2015. Total number of chassis were increased to 52 in the next year. These chassis are the same size as the 40 feet container.

Regarding the passage of chassis with Japanese single plate in Korea, logistics companies are granted to transport under the certain conditions by the permission of Korean authorities. The single plate chassis can be operated between Busan Old Port Ferry Terminal and Logistics Centre in Busan New Port hinterland. To transport flexibly without being restricted by such constraints, introduction of double plate chassis was necessary. To satisfy different vehicle standards of both countries, remodelling of chassis was indispensable. For example, two sets of air brake hoses connecting a tractor with chassis must be equipped based on the standard of Japan and Korea.

As a system for seamless logistics for Hakata Port, 75 side open containers are used in 2015. The total number were increased to 147 in the next year. These containers are the same size as the 40 feet container, but not only front and back doors but also the sides

are designed to be opened to improve cargo handling efficiency. There are two kinds of the side open containers, that is, double side open door containers and side open wing containers. The sides of the former type open horizontally, whereas the ones of the latter type open in the vertical direction. For this reason, the latter can be easier to find cargo handling location, but the manufacturing cost is higher. In automobile parts logistics emphasizing cargo handling efficiency, side open wing vehicles are common.

### **Operation of seamless logistics**

To Korean suppliers, the material requirements plan has been reported from Nissan in advance. When a fixed order was made six days before the assembly of the Nissan factory, the suppliers started to manufacture the parts. There are about 40 suppliers to be picked up parts around Busan, Gumi, Daegu, and Seoul. Chunil collects the parts 4 days before the assembly from remote areas and 3 days before it around Busan by 25 trucks by milk run through about 10 routes.

Chunil transports the parts to C & S International Logistics Centre (operated by Chunil) in the hinterland of Busan New Port 3 days before the assembly. It sorts parts in the order of the assembly without stocking the parts, and load them on chassis or side open containers. The total daily volume was about 16 FEU (40 feet equivalent unit) in total, of which 70% for Hakata Port and 30% for Shimonoseki Port in 2015.

Korea Nippon Express, which has AEO certification in Korea, declares customs in the morning of shipping day. In the afternoon, it drags the chassis and containers to the international ferry terminal in Old Busan Port, then the chassis are loaded on Kampu Ferry for Shimonoseki Port, and the containers on the Camellia Line for Hakata Port. The chassis is separated at the ferry terminal and fixed in the ship after being towed inside the ship by a cargo handling tractor. The side open container is carried into the ship by trailer, unloaded by reach stacker, and stacked in two stages. Impact of cargo handling by reach stacker is smaller than that by gantry crane, and almost same as that by using chassis. It is also unnecessary to carry in and out to container yards, and thus it can be transported in the same lead time as by the chassis.

Kampu Ferry departs at 21 o'clock every day and arrives at 7:45 the next day. Camellia Line departs at 22 o'clock every day and arrives at 7:30 the next day. As Nippon Express makes a preliminary declaration to customs during navigation, and the chassis and containers are ready to be taken out before the arrival. As soon as they arrive at ports in Japan, Nippon Express delivers them to the Nissan PLC about 40 km from Shimonoseki port and about 70 km from Hakata port by the afternoon two days before the assembly. When returning from Kyushu to Korea, empty returnable equipment are loaded on the chassis and containers.

By introducing the seamless logistics operation, the lead time has been shortened to 6 days including domestic buffers of 1 day, and it is about the same as domestic lead time. In addition, it made possible to be brought import parts directly to the PLC like domestic parts, thus warehouse for import parts became unnecessary. The parts inventory in this logistics system has been reduced to three days since arriving at the C & S international logistics centre, which is a drastic reduction from the previous 25 days.

### **The Effects of Seamless Logistics**

It is necessary to invest in special chassis, containers, and returnable equipment to introduce the seamless logistics systems. Although the investment costs are not disclosed, the effects must have overwhelmed the costs.

According to the trade statistics of Japan, the unit value of import automobile parts was about 580 yen (about 5.27 dollar)/kg at Hakata port and 670 yen (6.09 dollar)/kg at Shimonoseki port in 2015. Estimated value of parts per FEU was about 11.6 million yen (105 thousand dollar) at Hakata port and 13.4 million yen (122 thousand dollar) at



Shimonoseki port. Wi (2015) estimated that the door to door transport cost via Hakata port was about 302 thousand yen (2,750 dollar)/FEU and the one via Shimonoseki port about 205 thousand yen (1,860 dollar)/FEU. The rate of transport cost to the value of parts was so low as 2% that it is natural to import inexpensive Korean parts.

The reduction of inventory costs by the seamless logistics is also important. MLIT (2004) proposed to use time value for container in Asian trade as 1,800 yen (16.4 dollar)/FEU/hour for port development project. The introduction of the seamless logistics saved 22 days, that equalled the time value of 950 thousand yen (8,640 dollar).

### **Progress of Seamless Logistics Policy Among Japan, China and Korea**

The seamless logistics was triggered by the pilot project agreement at the Japan-China-Korea Logistics Ministers Meeting. In international logistics, the harmonization of international regulations and institutions is an important issue. The first Japan-China-Korea Logistics Ministers Meeting was held in 2006 to discuss joint policies for improving international logistics efficiency among three countries with deepening economic interdependence among them. After that, six meetings were held every two years until 2016

It has been an important objective to promote the creation of a safe, efficient, inexpensive and seamless logistics system in Northeast Asia from the beginning of this meeting. At the first meeting, they exchanged opinions on the improvement of seamless logistics system and reached an agreement that they would jointly study on the improvement of mutual passage of chassis.

At the second meeting in 2008, they evaluated the progress of the study on the mutual passage. They confirmed the status of the passage of foreign chassis among three countries and clarified the merits and concerns of mutual passage. They agreed to set up a working group (WG) on the mutual passage of chassis. Furthermore, they agreed to conduct survey on the standardization of small containers like 12 feet containers and standardization of pallets as well as international containers. At the third meeting in 2010, they evaluated the WG survey on the differences in related laws, the merits and demerits of the mutual passage of chassis, and the results of the pilot program.

Based on the agreement of close cooperation at the fourth meeting in 2012, Nissan Motor and Nippon Express started the seamless logistics project between Busan and Shimonoseki port. At the fifth meeting in 2014, Japanese and Korean government agreed to expand the pilot program between Busan and Hakata port and to relax the regulation on chassis management. At the sixth meeting in 2016, as the seamless logistics among Japan, China, and Korea has not been developed as expected, three governments agreed to study the possibility of pilot program further.

### **CONCLUSION**

Import of Korean parts by Japanese manufacturers is drawing attention as a new aspect of horizontal division of labour in Northeast Asia. It has been difficult to develop international parts logistics based on JIT principle in the actual business setting where various border barriers exist. This paper analysed how they have established seamless logistics systems, from various viewpoints such as shippers, logistics companies, governments and so on.

As for shippers, it grasped the production and procurement system of Nissan Motor Co., Ltd. and the supply chain of Nissan Motor Kyushu Plant, and clarified that the seamless logistics was positioned as an important means of procurement. As for the logistics company side, it clarified that Nippon Express was responsible for proposing and operating an efficient logistics system as 3PL. In international logistics where regulations and regulatory systems differ largely, it showed that policy harmonization through the

framework of the Japan-Korea Logistics Ministers Meeting and trade facilitation by the AEO system were important.

The Renault-Nissan Group has introduced the NPW and CMF at the global level. The import of Korean parts is increasing due to the production boost at the Kyushu plant. The seamless logistics is expected to support Asian optimal production and procurement systems to cope with foreign exchange risk. For other finished automobile manufacturers and parts makers, trade of parts among Japan, Korea and China is also becoming important, and seamless logistics is considered effective. At the Japan-China-Korea Logistics Ministers' Meeting, the establishment of a seamless logistics system in Northeast Asia has been a big issue for many years and it is necessary to proceed the meeting step by step.

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# COMPETITIVE MANUFACTURING FOR RESHORING TEXTILE AND CLOTHING SUPPLY CHAINS TO HIGH-COST ENVIRONMENT – A DELPHI APPROACH

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## ABSTRACT

Existing knowledge of reshoring, enabled largely by competitive manufacturing (CM) strategies in high-cost locations, is limited particularly in context to labour-intensive industries, like textile and clothing (T&C). The purpose of the paper is to identify and prioritize various CM-related supply chain factors that can enable reshoring of T&C to high-cost area. Following a systematic literature review, a multiple round Delphi study is conducted with T&C manufacturers in Sweden to seek practitioners' perspective. While there is high consensus on the success factors, flexibility to meet short lead times, high product/service quality, and product/service customization; low degree of agreement is reached for the perceived challenges. Some *out of literature* debates emerged in terms of challenges related to CM in high-cost area, regarding increased fixed costs of production, rise in inventory level due to high product variety requirement, and low skill level against access to skills. Along with the decisive knowledge on the CM-related success factors for reshored supply chains, the Delphi study offers an interesting practitioners' perspective from a labour-intensive sector like T&C.

## INTRODUCTION

Reshoring is an emerging supply chain phenomenon which has gained momentum in many industries (Kinkel, 2014), due to numerous challenges related to long distance trade and transactions. However, the existing knowledge of reshoring, enabled largely by competitive manufacturing (CM) capabilities in high-cost environment, is limited particularly in context to labour-intensive industries (Martínez-Mora & Merino, 2014), like textile and clothing (T&C) where skilled workforce, digital technology levels, and new business models are comparatively less evolved. Furthermore in T&C industries, where manufacturing location in low-cost countries is largely driven by low coupling and high formalization (Ketokivi et al., 2017), understanding what and how can existing high-cost manufacturing supply chain competitiveness reinforce reshoring requires specific attention. To clarify upfront, in our paper high-cost is defined by relevant input factor such as wage – largely determining the Gross Domestic Product (GDP) per capita of countries. Further, manufacturing supply chains encompass those activities of the value chain that are directly related to manufacturing the product and its components.

Although a wide variety of motivational factors and drivers for reshoring have been identified, e.g. locational, temporal, organizational and decisional (see Ketokivi et al. 2017; Kinkel and Maloca, 2009; Kinkel 2014), an understanding at the supply chain level, i.e. increased demand for speed and quality, necessitating more flexibility and closer relationships within supply chains, etc. (Mentzer et al. 2001) demands detailed attention (Ellram et al. 2013). By identifying and prioritizing such supply chain-related factors, and challenges, we are able to provide an understanding of what sets the competitiveness for T&C manufacturing supply chains in high-cost, essential to support further reshoring/relocation. Thus research question (RQ) 1 is: What are the key success factors and challenges related to the manufacturing supply chains of T&C in high-cost countries?

Similarly, specific attention is required to understand how these factors can affect the continued success of reshored manufacturing and sustain it in high-cost countries, more specific to labour-intensive industries, e.g. T&C. This perspective is important for examining the success of reshoring as the competitiveness of reshored manufacturing is largely dependent on supply chain competitiveness. Thus RQ 2 addressed is: What is the likelihood of the identified success factors leading to further reshoring of T&C production to high-cost countries?

To answer these RQs, the paper sets out to identify from the literature a comprehensive set of factors that may influence CM supply chains in high-cost environment. This is followed by a Delphi study carried out with a selected group of T&C industry practitioners to set their relative importance and seek motivation for these factors in influencing reshoring. For empirical data gathering, we concentrate on the region of west Sweden. Sweden can be considered as a high-cost country based on the parameters of GDP per capita (PPP) and average income per person. In line with few single industry-specific studies (Martinez-Mora and Merino, 2014), the focus of the study is on a particular region that has significance for T&C industry, as majority of Swedish apparel trade and cluster is located in the region (Lindqvist et al., 2008).

## METHODOLOGY

Given the purpose, a Delphi study is a viable research approach particularly to seek industry specific opinion. To elicit a consensus from a representative panel of experts a Delphi study is a systematic, iterative process (Okoli and Pawlowski, 2004) where panel is chosen carefully, comprising of knowledgeable and mutually anonymous respondents, as in our case through a selective sampling procedure described below.

In our study, a two-phase design of research was made. First, as the basis of the Delphi, a literature review was conducted in order to identify the success factors and challenges to CM. Various keyword search combinations with "reshor\*"/"backshor\*"/"rightshor\*", "supply chain", "local produc\*/manufactur\*", "competitive manufactur\*" along with "make-buy", "textile"/"clothing"/"apparel", and "local value/supply chain" were made in order to prepare a list of 23 and 9 challenges respectively. The final number of articles analysed was 20, published between 2013 and 2017 (*presented as a separate list in the reference section*). These success factors were categorized in the following groups: cost-related, time-related, product/production quality, service or innovation-related, relationships and others (see Table 1).

Subsequently, a modified Delphi was conducted. Participants for the modified Delphi study were chosen from an initial list of 183 companies operating in the T&C region in Sweden, consolidated from a number of industry sources and databases (e.g. ModeInk), of which 74 were selected on the basis of being directly involved with T&C manufacturing or related production processes (e.g. printing, dyeing). Only micro, small, and medium sized enterprises (MSMEs) were included as they constitute nearly 99.8% of Swedish T&C firms. The companies were contacted personally to interest them in participating in the study, resulting in a final sample of 19 companies (and 20 participants), 11 of which are producers and 8 service providers (e.g. dyers, printers, etc.). 9 of the 19 MSMEs have never outsourced their main activities. In line with literature (e.g. Okoli and Pawlowski, 2004) this is appropriate for constituting a Delphi study (optimum between 10 and 18) – thus with an acceptable response rate of 25.7%.

The Delphi started with a semi-structured interview round to facilitate the design of the questionnaire, i.e. elicit any addition to the lists of items (success factors and challenges) and provide further explanation to the importance of those identified. Conforming to a semi-structured procedure, the participants were presented with the list of items derived from the literature and with relevant explanations. The concepts of reshoring and high-cost local manufacturing are emerging with limited empirical data and literature reviews; therefore, the modified Delphi approach ensures better identification of these factors appropriate to the practitioners and the situation. Following the interview, the initial list success factors and challenges were finalized to 28 and 16, respectively (see Table 1). An

online questionnaire was devised for conducting the subsequent rounds of paring and ranking in the Delphi. For the rounds, we received a response rate of 70% for paring down, while 70%, 63%, and 63% for the three ranking rounds. Response rate for the future reshoring round was 60%.

The specific process of the ranking rounds of the Delphi was based on the method outlined in Schmidt (1997). The method provides explicit procedures and statistical measures to be used throughout the whole process. In the paring round, the practitioners were asked to select the most important success factors and challenges in order to ease the process of reaching a consensus in the next rounds. The paring down can be considered to be done when there are 20 or less items left (Schmidt, 1997). In line with Schmidt (1997)'s attempt to create a more consolidated list of randomly ordered items, we sought for simple majority of the responses (50% or more). This led to finally paring down the items to 12 CSFs and 8 challenges, considering that the maximum response counts for each item were 12 and 11 respectively.

Following the paring round, the final list of items were ranked in terms of their relevant and relative importance, meaning that rank 1 was assigned to the most important item while 12 and 8 to the least important success factors and challenges, respectively. At the onset of each online ranking round, controlled feedback was provided from previous rounds using a non-parametric statistical technique (Kendall's coefficient of concordance or Kendall's  $W$ ) to inform the outcomes of the previous rounds (Schmidt, 1997). Stopping rules were exercised after three rounds of ranking were conducted as we reached moderate consensus for the success factors, while lack of progress from round 2 was observed in the individual ranking orders for the "challenges" thus indicating a weak ranking agreement. After the ranking procedure, the same set of practitioners were contacted for evaluating the likelihood of how the listed CSFs can enable higher reshoring potential, on a 3 point Likert scale (1 = very unlikely to 3 = very likely).

To suit the successive stages of the modified Delphi study, data was analysed as per purpose. First, the list of items were determined via content analysis of the identified literature, and categorized based on a framework proposed in Sansone et al. (2017) which served as the guide for interviews. The interview data were structured to elaborate on or explain the factors identified through literature review, thus the coding was based on predetermined categories. However, new items were explored and added onto the list by directly asking the practitioners for more success factors and challenges. For the Delphi ranking rounds, guideline laid in Schmidt (1997) using non-parametric, non-probabilistic statistical analysis was followed. Each ranking round was evaluated for the strength of consensus with Kendall's  $W$  (value about 0.3 interpreted for weak agreement, 0.5 for moderate agreement, and 0.7 presenting a strong agreement). The controlled feedback mechanism facilitated the building of consensus, this means evaluation of: (i) mean ranks for the items, (ii) Kendall's  $W$  to determine the strength of consensus; and (iii) response rates supporting the inclusion of an item as important. As highlighted by MacCarthy and Atthirawong (2003) with the Delphi approach it is important to report and reason consensus achieved and also divergent opinions if full consensus cannot be reached. This was done by seeking support of relevant confirmatory comments from the practitioners obtained during the interview round. Kendall's correlation coefficient ( $T$ ) was also calculated to show the degree of correlation between two set of ranks accounting for and making adjustments for ties (Schmidt, 1997; Abdi, 2010).

## **IDENTIFYING FACTORS THROUGH LITERATURE REVIEW**

In light of the supply chain perspective on further reshoring to high-cost environment, the notion of competitive advantage of a firm related to cost, differentiation or focus (Porter, 2004) is crucial to be revisited. Previous research has shown cost factors to be the leading reasons for offshoring manufacturing; however, it has been proposed that increasingly consumer perceived value is being considered along with a more complete view of costs and profitability (Ellram et al., 2013; Fratocchi et al., 2016).

Different cost components and difficulties related to the complexity resulting from offshoring production have been found to be motivations for reshoring, including difficulties coordinating the supply chain (Kinkel, 2014; Kinkel and Maloca, 2009), problems with quality and flexibility (Kinkel and Maloca, 2009), and increased risk of disruption (Ellram et al., 2013). Increasingly, a more holistic view of costs related to manufacturing locations, including longer lead times leading to higher inventory levels and lesser flexibility and delivery ability (Kinkel and Maloca, 2009), can make the choice to manufacture locally more cost effective (Tate et al., 2014). Therefore, while location decisions, such as offshoring, have most often been made primarily for cost advantage, the resulting complexity can affect both costs and consumer value. Therefore, it is possible that manufacturing or producing locally through systematic planning of production/sourcing location can provide managers better information about total costs, as the supply chain is shorter, thereby leading to lower transaction costs, lower supply chain coordination costs, ease of quality assurance, and low inventory levels.

As previously mentioned, complexity in the supply chain resulting from offshoring has the potential to negatively affect the flexibility of a company's operations (Kinkel and Maloca, 2009). Unlike global products, products specific to the needs of the local market, demand more coupling with customer-specific post-production services (Ketokivi et al., 2017). This requires responsiveness to demand that can be enabled by both flexibility and agility (Wiesmann et al. 2017). Responsiveness can be achieved, e.g. as described by Martinez-Mora and Merino (2014), for smaller quantities and higher quality as in the Spanish footwear industry for producing smaller volume in order to respond to customer demands in a timely manner. Therefore, depending on the specifics of the industry and the expectations of the customers, producing locally can create benefits related to flexibility, responsiveness, and competing based on time.

Owing to the high degrees of complexity in managing dispersed production, relocating production or supply can ensure increased control. Such control can be beneficial to create opportunities locally, such as untapped capacity, optimal capacity utilization, or protection of capacity (Fratocchi et al., 2016; Bals et al., 2016). Additionally, increasing automation can reduce costs related to labor, and increase productivity in the high-cost area (Wiesmann et al., 2017; Tate et al., 2014). Changes in strategy can also provide benefits from multiple stages of production being located close together, including increased potential for innovation, higher quality and customization (Fratocchi et al., 2016; Ashby, 2016; Bals et al., 2016; Stentoft et al., 2016).

Additionally proximity to stakeholders, markets and customers can reduce complexities of offshore production, e.g. reduced demand responsiveness (Fratocchi et al., 2016; Ashby, 2016). Proximity to resources can be a significant motivation for relocation too (Ellram et al. 2013). There is also the potential for added meaning, or value related to production being located near to consumers (Ashby, 2016), which has the potential to strengthen relationships with the customer and facilitate greater access to invaluable customer knowhow or market knowledge (Joubioux and Vanpoucke, 2016).

There are additional potential benefits for relocating production, such as increased trust, and access to skilled workers or necessary know-how in the home country compared to offshore (Fratocchi et al., 2016; Wiesmann et al., 2017). Increasingly, more informal relationships and types of governance can allow a company to harness the tacit skills and expertise of the supplier, which can lead to greater visibility and sustainability (Ashby, 2016). Thus, there are potential benefits to having proximity to market and necessary resources, including skilled labour and know-how, and proximity to strategic supply chain partners. Other benefits identified include, increasing awareness of sustainability issues (Wiesmann et al., 2017; Tate et al., 2014; Ellram et al. 2013), and transparency of the value chain (Ashby, 2016).

## **RESULTS: SUCCESS FACTORS, CHALLENGES AND FUTURE RESHORING**

As the starting point, success factors and challenges are identified from literature and the former being categorized beyond Fracocchi et al. (2016)'s interpretive framework on cost (C) vs. consumer perceived value for motivating reshoring. Value in our paper is subcategorized in terms of its driver, as relating to cost (C), time and flexibility (T), factors determining production and/or product quality, service and innovation (P), relationships (R), and other aspects (O). Quality is considered to be an aspect related to product and production as well as a cost incurred for ensuring required quality. Relationships such as with customers, suppliers, or other strategic partners are conceptualized. The Other category encompasses the remaining factors, including environmental factors, transparency and consumer perceptions. Table 1 highlights these factors derived from literature and also added to from practitioners' response. Further the results of the paring round are also presented<sup>1</sup>.

**Table 1.** Manufacturing supply chain related success factors and challenges for reshoring

Table 1: Manufacturing supply chain related success factors and challenges forreshoring		
Items from literature review	Items after interview	Support from interview round
Key Success Factors		
C		
Better information about total costs	Availability of total cost information (4)	Of trivial importance, confirmatory validation not requisite
Ease of quality assurance	Easier quality assurance (3)	
Low inventory levels	Low inventory levels (3)	
Lower supply chain coordination costs	Low supply chain coordination costs (1)	
Lower transaction costs	Low transaction costs (0)	
Systematic planning of production/sourcing location	Production location planned carefully (0)	
T		
Operational flexibility	Flexibility to meet short lead times (12)	Ability to deliver quickly is one of the main benefits of producing locally. One participant explained that the company's reputation to deliver high quality, fast is very important.
Better agility	Flexibility to respond to changes in demand (number and type of products) (9)	Being able to meet customer demand for small order sizes to be able to change between products quickly.
Better responsiveness		
	Flexibility of purchasing practices (suppliers offering small batch sizes/no minimum orders) (7)	Ability to buy smaller quantities for maintaining relationships with suppliers for those selling inside Europe.
P		
Customization product strategy	Customized product and/or service (11)	Participants described customization as a capability important to produce customer-specific products and services.
Higher control and efficiency of production and supply chain	High control and efficiency of manufacturing or supply chain (dependability of delivery) (11)	Better control of the SC was enabled by producing locally - important aspect for competitiveness. Co-location of activities was mentioned in having a big role as enablers for high

<sup>1</sup> Note: The items in italic are new additions from interview round; the rows in   are those with simple majority (50% or more) of the responses out of the maximum response counts for each factor (12 and 11 for CSFs and challenges respectively). Interview supports are included.

		control and efficiency, leading to dependability of delivery.
Optimal capacity utilization	Available production capacity (8)	Available capacity that could be better utilized. Capacity for many is a seasonal issue with times with not enough capacity and times with not enough demand.
	<i>Extremely high quality of product and/or service (8)</i>	Need to offer a high quality of service, e.g. taking care of many aspects of production for the customers.
Increased potential for innovation	High potential for innovation (6)	Being located here in Sweden allows for high potential for innovation.
	<i>Specialization of production and/or service (6)</i>	Able to do some aspects of production which cannot be easily copied.
Automation of production and use of digital technology	Automation and digital technologies (5)	Of trivial importance, confirmatory validation not requisite
High productivity of local labour/production	Highly productive local labour (5)	
	<i>Quality of distribution in the area (4)</i>	
Lower risk of supply chain disruption	Low risk of supply chain disruption (3)	
Change of production/sourcing strategy	Co-location of multiple steps in the supply chain (design, production, etc.) (2)	
<b>R</b>		
Proximity to market	Closeness (geographical and cultural distance, close relationship) to customers (7)	Being in the same country as customers is a benefit but sharing the same general culture and/language can be more important.
Proximity to necessary resources	Closeness (geographical distance) to skilled labour and know-how (6)	Proximity to skilled labour and know-how as a benefit for being able to seek support. However, mostly seen as a challenge.
Proximity to strategic partners	Closeness (geographical and cultural distance, close relationship) to suppliers and strategic partners (2)	Of trivial importance, confirmatory validation not requisite
<b>O</b>		
Environmental issues	Commitment to environmental protection (8)	Environmental protection is key and that the company's interest is stronger than the customers.
	<i>Consumer awareness of the benefits of producing locally (quality, speed, sustainability)</i>	Of trivial importance, confirmatory validation not requisite
	<i>Company's ownership</i>	
Strong Intellectual Property (IP) protection	Strong IP protection (legal rights to designs or patents)	
Higher transparency within the supply chain	High transparency of the supply chain	
Challenges		



Lack of skilled workers	Lack of skilled labour (11)	Lack of necessary education, not easy to find skilled seamstresses locally.
	<i>Balance low inventory with high variety (11)</i>	Difficulties with producing and keeping a stock of high variety of products.
Higher costs related to local regulations	High costs due to strict labour regulations (9)	Higher costs making local making less competitive.
	<i>High fixed costs with own production (8)</i>	Difficulties with having higher fixed costs as requests are small and fluctuating.
	<i>Supplier minimums too high (7)</i>	Minimum volume requirements are high, being MSME we cannot buy so much.
	<i>Increasingly short lead time expectations and fast changing fashions (6)</i>	Big challenge to meet short time of ~2 weeks due to fashion seasonality, fluctuating demand.
Lack of know-how	Lack of know-how (6)	Hard to find personnel who knows the textile in practice
	<i>Lack of consumer awareness of local production and benefits (both B2B and end user) (6)</i>	Consumers (both B2B and end user) are not aware of and are not willing to pay for the benefits of producing locally (high quality, speed, sustainability etc.)
Higher costs related to local regulations	High costs due to strict environmental regulations (2)	Of trivial importance, confirmatory validation not requisite
Inadequate production capacity	Inadequate production capacity (3)	
Lack of complete information for location decision-making	Lack of complete information for location decision-making (2)	
Limited availability of distribution/supply networks	Limited access to foreign distribution networks (2)	
Lack of raw materials and components	Lack of supply networks for raw materials and components (3)	
Loss of proximity to offshore market(s)	Limited access to foreign customers (3)	
Loss of strategic partners offshore	Limited access to foreign suppliers (2)	
	<i>Mismatch between new technologies and quality required (3)</i>	

The results of the three Delphi ranking rounds carried out with the selected success factors and challenges in order to reach consensus among the practitioners, is presented in Table 2 in terms of the mean rank of each item in each round. The three most important T&C manufacturing supply chain-related success factors for further reshoring to a high-cost area were identified as: Rank 1. flexibility to meet short lead times, Rank 2. extremely high quality of product and/or service, and Rank 3. customized product and/or service. Low agreement was reached for the challenges, however the ranking rounds resulted in revealing challenges of high costs due to own production or due to strict labour regulations, and balancing low inventory with high variety, as the important three for further reshoring to a high-cost area.

**Table 2.** Mean ranks of key success factors and challenges after each Delphi round<sup>2</sup>

Key success factors	Mean rank			Future reshoring (Averaged Final order rank)
	1. round	2. round	3. round (Final order rank)	
Flexibility to meet short lead times	3,6	2,6	1,4 (1)	2,5 (2,5)
Extremely high quality of product and/or service	4,6	3,4	3,8 (2)	2,7 (1)
Customized product and/or service	5,0	5,3	4,3 (3)	2,3 (6)
High control and efficiency of production or supply chain	6,5	6,4	5,2 (4)	2,4 (4)
Flexibility of purchasing practices (suppliers offering small batch sizes/no minimum orders)	6,7	5,8	5,8 (5)	2,3 (6)
Flexibility to respond to changes in demand (number and type of products)	6,1	7,6	6,6 (6)	2,3 (6)
Available production capacity	6,2	6,0	7,0 (7)	1,8 (11,5)
Specialization of production and/or service	6,6	6,8	7,3 (8)	2,5 (2,5)
Commitment to environmental protection	7,9	7,9	8,0 (9)	2,0 (8)
Closeness (geographical distance) to skilled labor and know-how	8,1	8,5	9,4 (10)	1,9 (9,5)
Closeness (geographical and cultural distance, close relationship) to customers	8,6	8,3	9,6 (11)	1,8 (11,5)
High potential for innovation	8,0	9,3	9,7 (12)	1,9 (9,5)
Challenges	Mean rank			
	1. round	2. round	3. round	
High fixed costs with own production	3,6	2,1	2,3	
High costs due to strict labor regulations	3,7	3,8	3,6	
Balancing low inventory with high variety	4,4	4,3	3,7	
Lack of skilled labour	3,7	4,3	4,1	
Lack of consumer awareness of local production and benefits	4,4	4,9	4,5	
Increasingly short lead time expectations and fast changing fashions	5,4	4,5	4,9	
Lack of know-how	4,6	5,3	5,8	
Supplier minimums too high	6,1	6,9	7,2	

Given that total 12 CSFs and 8 challenges and 14, 12, and 12 practitioners in rounds 1, 2 and 3 respectively, the Kendall's W is further calculated after each round. The consensus in the first round was fairly low (0.18) for success factors and 0.13 for challenges. During the next two following rounds, the consensus increased to 0.32 and 0.31, respectively, and finally to 0.5 and 0.36. The Kendal T was = 0.604, thus showing significant correlation between the importance of factors contributing to CM and that are perceived to lead further reshoring in the high-cost area.

## CONCLUDING DISCUSSION

<sup>2</sup> Mean Rank 1 is the relative best; Future reshoring is presented on 1-3 Likert scale where 1 - very unlikely to 3 - very likely.

Both confirming and deviating evidences are found through the study. Specifically, the ability to be flexible in production to meet short lead times was important to produce competitively in high-cost area (e.g. Fratocchi et al., 2016). However, the need for high quality materials (another success factor) in local production led to difficulties in meeting short lead times as ordering high quality yarns could require up to many months. On the other hand, high customer service was adjudged to be a key benefit of meeting short lead times when producing locally (Kinkel and Maloca, 2009). High quality was related in most cases to product/service and production quality, and aspects of sustainability – which was ensured through regional sourcing for better control. This close attention to quality can also be related to the potential for innovation whereby co-location of development and production enable developing higher customer value (Ketokivi et al. 2017). In connection, high priority was given to customization and customer-specific production (e.g. Fratocchi et al. 2016; Weismann et al. 2017). Specialization in terms of focus differentiation of products and services (Porter 2004) was described as important for sustaining business. On the contrary, in some cases having customer specific production meant sacrificing product quality based on the needs of the customer, much because of the challenge of lacking customer awareness of the benefits of producing locally and the willingness to pay for it. While closeness to customer was not highly ranked, the need for close relationships with customer is integral for customized, or specific production (Ketokivi et al. 2017), thus sharing the same culture/language was seen to ease development of long-term relationships. However, more than adding benefit is was considered more as the way of doing business.

Limited consensus, both among practitioners and that with extant literature, was seen among the challenges to producing in a high-cost area. For example, a high fixed cost related to production was a challenge acknowledged by many, especially due to the seasonality of demand, and contradicts research that has suggested increasing cost-benefits as motivations for reshoring (e.g. Kinkel, 2014). Additionally, the need to provide a wide variety of products and services to customers was seen as a challenge to inventory levels, much different to previous findings suggesting that local production can lead to lower inventory levels (e.g. Ashby, 2016). This difficulty can be related to the challenge of supplier minimums being too high, seen as challenging rather than success factor, opposing the general claim of total cost saving with reshored production (e.g. Wiesmann et al., 2017; Fratocchi et al., 2016). Further finding skilled labour and knowhow rather than confirming the motivation to reshoring to access skills (e.g. Fratocchi et al., 2016; Wiesmann et al., 2017), was seen as a challenge attributed to the absence of manufacturing competencies that have resulted from extensive offshoring in labour-intensive industries (Martinez-Mora and Merino, 2014).

Regarding the likelihood of how the foregoing factors would enable future reshoring, there was fair agreement among the practitioners. This result is in line with motivations in literature relating to difficulties with quality and flexibility offshore (e.g. Kinkel and Maloca, 2009).

The main contribution of the study is the practitioners' identification and prioritization of the key success factors and challenges to producing T&C in a high-cost area. As future research, the findings can be used to build upon theories emerging in the 'shoring' (location decision) and 'sourcing' (make/buy decision) literature (Ketokivi et al., 2017), and also to develop decision-support models based upon the prioritized success factors.

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# INVESTIGATING THE IMPACT OF CLIMATE CHANGE ON FOOD SOURCING DECISIONS

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## ABSTRACT PURPOSE

The forthcoming climate changes are expected to pose significant challenges to the food industry, as they will affect the yield of different crops. As a result, sourcing decisions of certain food items will need to be reconsidered in the years to come. In this paper, we investigate how environmental changes will affect agriculture and how companies should be making food sourcing decision within the context of climate change.

## APPROACH

In this paper, we propose a three-stage methodology that can be used to evaluate the suitability and risk of crops and guide sourcing decisions. In the first stage of the methodology weather uncertainties are modelled using data from the WORLDCLIM database. This is necessary in order to define a notion of risk in the growing of the crops. In the second stage the current and future suitability of different crops is assessed taking into account weather uncertainties. In the third-stage sourcing decisions are made using the suitability and risk levels of crops. A mathematical framework using mean-variance analysis is developed to calculate the optimal sourcing decisions.

## FINDINGS

This study shows that climate change is indeed going to have an impact on supply chains in the future, as certain food items might be less profitable while others have to be produced in different areas of the world. The results indicate that changing the location of investments (in terms of sourcing decisions) will be crucial in order to benefit from optimal profits. A trend towards an increase in risk in food supply chains due to climate change is also observed in this study.

## VALUE

This is perhaps one of the first studies studying future sourcing decisions due to climate changes. It also considers both the suitability and risk of geographical areas for agriculture. Scholars can use the proposed methodology to further understand the changing nature and risk of food supply chains. Companies can benefit by understanding the risk and return of their sourcing decisions.

## RESEARCH LIMITATIONS

Crop suitability is a complicated matter and it is difficult to give an accurate view of suitability. In this study, only atmospheric conditions were taken into account, leaving aside other factors like soil quality and availability of water. Such factors can be considered in further developments. Another limitation to this study is the impact of policies on the food supply chain, which can have important effects on agricultural exploitation, but are unknown in a long-term study.

## PRACTICAL IMPLICATION

The results of this study indicate that suppliers need to re-consider their long-term strategy when it comes to sourcing food items from certain areas of the world. This might require building relationships with suppliers from new countries in order to be ready for the future.

## INTRODUCTION

Climate Science findings predict that human induced climate change will bring large scale environmental changes such as sea-level rise, flooding, extreme weather events, and heat waves with potentially catastrophic consequences for industries and society. In 2012, a prolonged drought hit the Midwestern United States which resulted in record low water levels on the Mississippi river, forcing transport company Cargill Inc. to operate its barges at 13 per cent below normal capacity (Plume, 2012). The cost from the drought to Texas farmers have been US\$2.1 billion in livestock losses and US\$3.1 billion in crop losses (NBC News, 2011). Therefore, climate change will create significant challenges in the global food sourcing, as it will impact on crop growth and yields. Climate change is expected to affect both the suitability of different regions to grow certain crops but also the risk of producing low quality food items. Consequently, organisations need to adapt and devise a novel location decisions approach for sourcing certain food items. This approach should guide organisations to choose areas with greater profitability while making them resilient to unforeseen changes.

In this paper, we thus propose an approach to investigate the impact of environmental changes on the suitability and risk of growing crops in different geographical areas, and examine how this might affect the sourcing decisions. The proposed approach is applied to a case example to demonstrate its applicability to food sourcing decisions.

## BRIEF LITERATURE REVIEW

Yield is a central variable in food production. It determines the amount of resources (land or any other) required in order to produce a given amount of food. Crop yields are important as production of crop foods accounts for 83% of the total food production (Kummu et al., 2012). Yields tend to decrease as a direct consequence of climate change and other degradations in crop growth. This decrease, when considered together with the increase in global population, creates challenges not only for sourcing decisions but food consumption in general.

Climate change, together with changes in agricultural conditions, including potential changes in soil suitability and increased frequency of extreme weather events is a major challenge for the food industry. This is a source of a major part of the uncertainties for agricultural production in the future and is an important field of study (Alva-Basurto & Arias-González, 2014; Laderach et al., 2011; Mutshinda, Finkel, & Irwin, 2013; Wilson & Silander, 2014).

## APPROACH

In this section, we propose a modelling approach to evaluate the impact of climate change on the ability to grow crops, and thereby assess the required changes in future sourcing decisions. The approach has three sequential stages. In the first stage, weather uncertainties are modelled in order to predict potential climate changes. These uncertainties are then used in the second stage to evaluate the current and future suitability and risk of certain crops in different geographical locations. Finally, the estimated suitability and risk are used in a model that allows companies to make sourcing decisions taking into account both critical factors. Figure 1 graphically illustrates the approach, which will be described stage by stage in the remaining of this section.

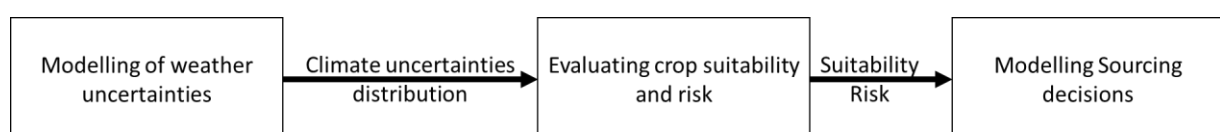


Figure 1: Modelling framework to assess the impact of climate change on food sourcing decisions

### **Modelling Climate Uncertainty**

Changes in the weather generally results in variations in temperature and average rainfall. These variations have a direct impact on the ability to grow crops. However, these variations are uncertain in nature and they depend on the region of analysis. Historic data of rainfall and temperature of various regions (e.g Europe, Asia, North America) will need to be used to fit a suitable probability distribution that best describe the variations in temperature and rainfall and determine the distribution's parameters. Notice that it is the variance of a distribution that will represent the uncertainty of the weather conditions.

The various steps in this stage are:

- a. Gather historical weather data (temperature and rainfall) for the region of interest. This can be for specific cities or countries and also depends on data availability.
- b. Find a probability distribution that best describes the historical weather data. Firstly, different types of possible representations of the variances are defined and are evaluated for various probability distributions. The evaluation of fitness can be carried out using chi-square tests and the resulting p-values. Each probability distribution along with the choice of variance is scored for best fit and selected for further analysis.
- c. The weather related information is generally represented as bio-climatic variables and these variables are used to track climate changes in the future. Therefore, we need to assess the climate variability in terms of those variables. In total, there are 19 bio-climatic variables defined. However, for this specific study we choose bio3 (isothermality) and bio4 (temperature seasonality- standard deviation of monthly means) for representing the temperature changes. For representing the rainfall, we use the difference of bio13 (precipitation of wettest month) and bio14 (precipitation of driest month), along with bio 15 (precipitation seasonality). These variables were chosen because they possibly best describe the extremes and seasonality of the weather pattern. We estimate theses bio-climatic variables based on the historic weather data from the various regions, and use least squares fit to calculate the parameters (mean and variance) of the probability distributions as a function of bio-climatic variables. This is done for both temperature and rainfall parameters.

The output of this first stage is a weather uncertainty model described as a function of bio-climatic variables.

### **Crop suitability and risk**

In the second stage of the approach, crop suitability is established based on atmospheric criteria with the uncertainty in weather represented from the previous stage. Changes in weather pattern impact on the ability to grow crops. The uncertainty associated with climate change may result in a situation where certain crops can be grown in new areas where it was not possible previously. On the other hand, some of current crop regions will be affected by climate change. Therefore, to assess the impact of climate change on crops, a suitability model is developed.

The key drivers that have an impact on crops are resistance to frost, temperature and rainfall. The resistance to frost stipulates that the minimum temperature should be above a threshold for the crops to withstand extreme weathers. The FAO Ecocrop (<http://ecocrop.fao.org/ecocrop/srv/en/home>) model provides the data with regards to the optimal parameter for a particular crop to grow effectively. The parameters include maximum and minimum temperature required, and the average rainfall required. This data will be used assess the suitability of the crops.



To assess the future suitability of crops based on climate change, we utilise the data provided by WORLDCLIM (Hijmans, et al. 2005). This data provides an estimate of bi-climatic variables for various years in the future. In this study we choose 2050 as the year of assessment. Various climatic conditions are simulated  $N$  times based on the uncertainty model developed in the previous section along with the WORLDCLIM dataset to produce future temperature and rainfall characteristics. The simulated results are compared with FAO Ecocrop model and an average suitability score is given (0 to 1).

With regard to risk, this is defined as the percentage of deviation from the mean suitability. For instance, 10% risk corresponds to a situation of risk if the suitability calculated is below 10% of the mean value. We assume the temperature and the rainfall risk are independent and therefore the total risk is defined as:

$$Risk = 1 - (1 - risk_{temp}) * (1 - risk_{rainfall})$$

Based on the above procedure, this stage produces an average future suitability of crops and their associated risks for a particular region of interest.

### Sourcing decision model

Changes in the weather will have an impact on the suitability of crops growing in a particular region; this will then have a further impact on a company's ability to source food. Therefore, the sourcing decision model is modelled as a supplier selection problem, where suppliers are various regions where the food is sourced from. We model the sourcing decision as a mean-variance model, which takes a list of suppliers, their costs and risks, and determines the quantity of order to each of them for a given probabilistic demand scenario. In this paper, we assume the demand to be deterministic as it will be difficult to obtain the probability distribution of the demand in the future. The mean variance model is presented below:

The quantity delivered by a supplier  $i$  can be written as:

$$m_i = Q_i * y_i * b_i + Q_i * (1 - b_i)$$

Where:

- $Q_i$  is the quantity ordered to supplier  $i$
- $y_i$  represents which part of the order is met in case of failure. 10% was taken (risk 10%).
- $b_i$  is a binary variable representing the success/failure of the supplier (1 = failure)

The value for the company that is sourcing, can then be written as:

$$\Pi = \begin{cases} s * \sum_{i=1}^n m_i - k * \left( x - \sum_{i=1}^n m_i \right) - c * \sum_{i=1}^n m_i & \text{if } \sum_{i=1}^n m_i \leq x \quad [SHORTAGE] \\ s * x + r * \left( \sum_{i=1}^n m_i - x \right) - c * \sum_{i=1}^n m_i & \text{if } \sum_{i=1}^n m_i > x \quad [SURPLUS] \end{cases}$$

Where:

- $S$  is the selling price for one unit
- $r$  is the value of one unit of goods in inventory
- $k$  is the loss of goodwill in the case of one unit of unmet demand
- $x$  is the demand
- $c_i$  is the cost of one unit from supplier  $i$

The above equation can be written as:

$$\Pi = \sum_{i=1}^n m_i * (s - c_i + k) - k * x - (s - r + k) \left( \sum_{i=1}^n m_i - x \right) * \delta_{\sum_{i=1}^n m_i > x}$$

Where  $\delta$  represents the Kronecker delta.

The mean and variance can then be written as:

$$E(\Pi) = \sum_{i=1}^n \alpha_i * E(m_i) - k * x - \beta E \left( \int_0^{\sum m_i} \delta_{\sum_{i=1}^n m_i > x}(t). dt \right)$$

$$var(\Pi) = \sum_{i=1}^n \alpha_i^2 * var(m_i) + \beta^2 * var \left( \int_0^{\sum m_i} \delta_{\sum_{i=1}^n m_i > x}(t). dt \right) - 2 * \beta$$

$$* \sum_{i=1}^n \alpha_i * cov(m_i, \int_0^{\sum m_i} \delta_{\sum_{i=1}^n m_i > x}(t). dt)$$

Then according to the mean-variance model, the maximising function can then be written as:

$$MV(\Pi) = E(\Pi) - A * var(\Pi)$$

where  $A$  is the *risk averseness*. This is the factor used in order to determine how much value the user is ready to trade for a certain decrease of variance (uncertainty).

Using the above model, it is possible to calculate the changes in value due to sourcing a food from a particular region. In the next section, we present a case example to illustrate the application of the proposed methodology.

## CASE EXAMPLE

### Introduction

To demonstrate the application of the methodology, we use banana as an example item. Banana is one of the key fruit that is imported into most of the developed countries and there is demand to supply bananas all year round to these countries. Applying the methodology will reveal the impact of climate change on banana growing regions and thereby allow companies to decide on their sourcing strategy for the future. In terms of the region of analysis, we focus on South America (north), South America (south), central Africa and Oceania. These regions currently represent the most of the banana growth in the world. The next sections explain the application of the methodology, state by state, in order to understand the implications for sourcing decisions for banana.

### Modelling Climate Uncertainty

Four cities were chosen to gather historical data regarding the global weather pattern. These four cities are London, New York, Marseille and Beijing and were chosen because of the availability of historical weather data. The data consists of temperature and rainfall per month over a period of 64 years.

To represent the weather uncertainty, the normal distribution was used to model the temperature variations and gamma distribution to model the rainfall. These distributions are well suited to represent the natural phenomenon. Further, we defined various possible choices of variance:

- Equal for every month, but such that the sum of the monthly variances is equal to the variance of the yearly values

- Equal to the mean, multiplied by a coefficient (the same for every month) such that the sum of the monthly variances is equal to the variance of the yearly values
- Equal to the minimum of the monthly variances
- Equal to the mean of the monthly variances
- Equal to the maximum of the monthly variances

Chi square tests were applied to each of the proposed distribution to evaluate the fitness. P-value from chi-square tests was used to rank each models. Temperature uncertainty was best described by a normal distribution with a variance for each month equal to the variance of each city. Rainfall is best described by using a gamma distribution whose variance represents the sum of the monthly variances which equals the annual variance.

To calculate the parameters of the models, we calculate the bio-climatic variables for each of the four cities and use least square fit. First, we calculate the annual standard deviation of the temperature and then we calculate the monthly standard deviation. The following lists the relation between the bio-climatic variables and the parameters:

$$stddev Annual Tmin = \begin{bmatrix} 0.148945 \\ 0.001043 \\ -4.53001 \end{bmatrix} * \begin{bmatrix} bio3 \\ bio4 \\ 1 \end{bmatrix}$$

$$stddev Annual Tmax = \begin{bmatrix} 0.148945 \\ 0.001043 \\ -7.21251 \end{bmatrix} * \begin{bmatrix} bio3 \\ bio4 \\ 1 \end{bmatrix}$$

And the monthly standard deviations are given as:

$$mean stddev Tmin = \begin{bmatrix} 1.04081 \\ 0.737734 \end{bmatrix} * \begin{bmatrix} annual std Tmin \\ 1 \end{bmatrix}$$

$$mean stddev Tmin = \begin{bmatrix} 1.04081 \\ 0.898538 \end{bmatrix} * \begin{bmatrix} annual std Tmax \\ 1 \end{bmatrix}$$

Similarly, for the rainfall, we get the standard deviation as:

$$stddev Annual Rainfall = \begin{bmatrix} -0.001012 \\ 0.265156 \\ 0.184704 \end{bmatrix} * \begin{bmatrix} bio13 - bio14 \\ bio15 \\ 1 \end{bmatrix}$$

Based on the above parameters of the probability model for temperature and rainfall, we can model the uncertainty in the weather. In the next step, we utilise this to model the suitability and risk for banana crop.

### **Crop suitability and risk**

Based on the above equations and using rcp60 data from WORLDCLIM, various climatic scenarios were simulated and suitability and risk were calculated. The simulations were done for N=500 times. Figure 1 shows the difference between the current and future suitability for the banana crops. The regions of high suitability areas remain the same across the various regions. These values are used in the mean-variance analysis for sourcing decisions.

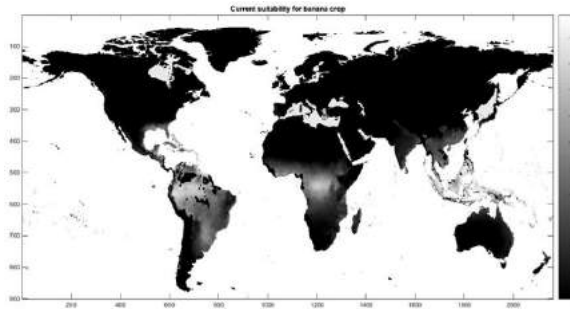


Figure 1a: Current suitability of banana crop

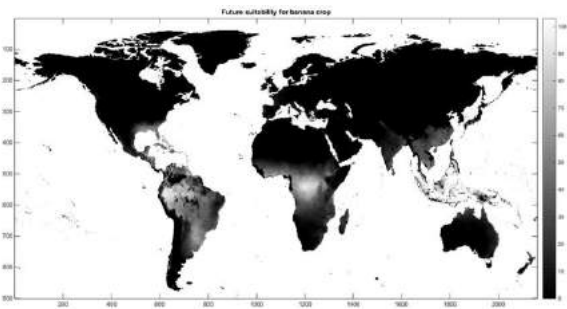


Figure 1b: Future suitability of banana in 2050

The suitability and the risks associated with banana are shown in Table 1. From Table 1, it can be seen that the available area for banana for South America (north) decreases, while the available area increases for central Africa.

Table 1: Current and future suitability and risks for banana for each region

Area Name	South America (North)	South America (South)	Central Africa	Oceania
<b>Coordinates</b>	(921,607) – (523,473)	(921,733) – (608,607)	(1314,591) – (976,483)	(2116,620) – (1608,460)
<b>Suitability current</b>	71.90%	57.45%	64.38%	80.11%
<b>Risk 10% current</b>	23.34%	26.07%	24.18%	25.75%
<b>Cost current</b>	8.34	10.44	9.32	7.49
<b>Area current</b>	4,457,100km <sup>2</sup>	1,125,500km <sup>2</sup>	1,125,500km <sup>2</sup>	3,442,100km <sup>2</sup>
<b>Suitability future</b>	60.09%	58.13%	69.39%	68.70%
<b>Risk 10% future</b>	36.66%	28.06%	24.89%	36.48%
<b>Cost future</b>	9.99	10.32	8.64	8.73
<b>Area future</b>	3,069,800km <sup>2</sup>	1,298,900km <sup>2</sup>	3,144,400km <sup>2</sup>	2,849,000km <sup>2</sup>

### Sourcing decision model

In this particular example, the assumed input values for the sourcing decision model are:

- $S = \$1.00$ , the selling price for one unit (1 kg)
- $r = 10\% S$ , the value of one unit of banana in inventory
- $k = 25\% S$ , the loss of goodwill in the case of one unit of unmet demand
- $x = 100$ , the demand

The cost of growing banana is a function of suitability. A low value of suitability indicates that the yield will be lower or might need more investment to get the same rewards. Therefore, the cost is given as:

$$C = \frac{0.6}{\text{Suitability}}$$

The mean-variance analysis proposed in section x is applied with the data from Table 1 and the results are shown in Table 2.

Table 2: Optimal sourcing decision for banana

Area name	Current Optimal Decision	Future Optimal Decision
<b>South America (North)</b>	127.58	10.41
<b>South America (South)</b>	0	8.71
<b>Central Africa</b>	3.64	117.03
<b>Oceania</b>	56.77	55.89

From Table 2, it can be inferred that the current sourcing strategy to maximise profit will be to source from north of South America. However, due to changes in climate it might be better to source from central Africa in the future. The values in the table indicate how many units the company should order from each region given the risk. As the risk of climate change increases, the mean-variance analysis proposes that the company should order 192 units in total in the future compared to the current 188 units, indicating the increase in risk.

## CONCLUSION AND FUTURE WORK

In this paper, we propose a methodology for making food sourcing decisions by considering the impact of climate change in the future. The method uses the data from WORLDCLIM to model the suitability of growing crops due to climate change, which is then applied to a mean-variance model to determine the optimal sourcing strategy. The proposed methodology was applied to banana crop. The results indicate that climate change will affect the way companies source food. The methodology is generic and can be applied to a particular region of interest and also for a crop of interest. The main limitation of the model is that it does not include soil type and other aspects that might have an impact on the suitability of crops. This study only considers atmospheric conditions such as temperature and rainfall. Further studies that include this type of analysis therefore need to be conducted to improve our understanding of the way weather changes will affect future sourcing decisions.

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# **A SIMULATION-BASED OPTIMIZATION MODEL FOR ATTENDED DELIVERY TIME SLOT MANAGEMENT**

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## **ABSTRACT**

Offering customers the choice of delivery time slots is an emerging business strategy in attended home delivery service because it has potential to improve service level, reduce the risk of delivery failure, increase system utilization, and shift some peak demand to off-peak time slots. In this study, a simulation-based auction model is developed for assisting attended delivery service providers with pricing decisions, while also improving the matches between customers' and service providers' preferred time slots and fees, and maximizing the total system. The study starts from managing homogenous time slots with three kinds of customers' behaviours (i.e. price-taker, price-bidders, and leave-without-pay) and then considers heterogeneous time slots. Our study finds that the optimal system revenue may vary depending on different posted and minimum acceptable bidding prices, the heterogeneous characteristics of time slots, the appropriate timing of the price markups and/or markdowns, and interrelation between customers' behaviours and reference prices.

## **INTRODUCTION AND BACKGROUND RESEARCH**

Freight transportation systems are key contributors to entire supply chains while providing strong linkages among production operations through the efficient movement and timely availability of finished products. Managing last mile delivery is an emerging business, since online shopping has grown in popularity with customers and grocers alike in recent years. According to the Berning et al.'s survey results, the online grocery market reached an annual growth rate of 42% in the United States since 2003 (1). Forrester Research indicates that online grocery sales in Europe and USA increased during 2010 from nearly 6.7 billion euros and \$5.8 billion USD in 2005 to 34 billion euros and \$16.9 billion USD, respectively (2, 3). However, delivery failures still increase the difficulties in attended delivery logistics.

This issue is an especially important concern for attended delivery, which needs consignees to be present to confirm the receipt of the products. Since there are many uncertainties about the shipment arrival date and time, if deliveries fail, carriers have to schedule re-deliveries with higher operating costs and lower customer satisfaction. A recent survey in Taiwan indicates that 48.2% of respondents prefer to select their desired delivery time slots (Source: InsightXplorer Ltd., 2011.)

Although offering such delivery service can provide customers more conveniences (e.g. higher service quality, shorter waiting times, more efficient operations, and more customer choices), only a few service providers in Taiwan currently allow customers to select their preferred time slots. However, the durations of service time slots are still somewhat excessive (e.g. 6 hours in city logistics) to insignificantly reduce the expected

waiting time. In addition, demand unpredictability, strict delivery time windows, and low profit margins increase challenges in attended delivery.

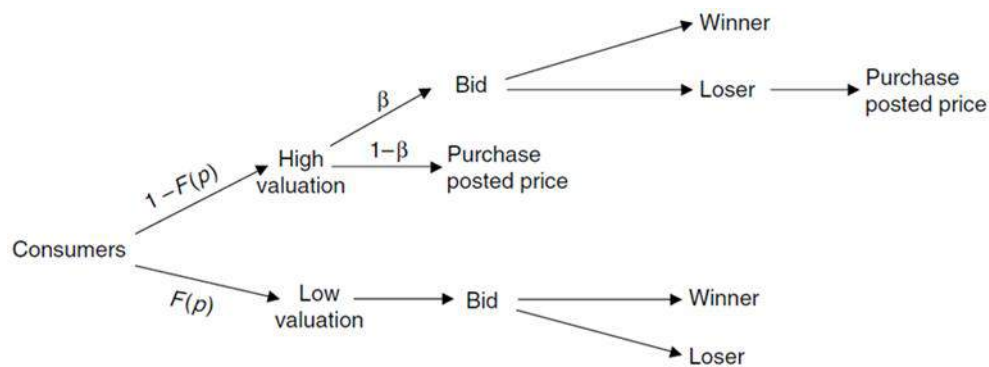
For improving the efficiency and reliability of conventional attended home delivery service, offering customers a choice of desirable shipping time slots becomes an innovative approach. Thus, an auction-based mechanism is designed to maximize the total service providers' expected revenue, while also offering more flexibility for customers in selecting their preferred time slots. Several research questions discussed in this study: (1) instead of arbitrarily making incentive decisions (e.g. Peapod Online Grocery Shopping and Delivery Service in USA), how can we quantify and optimize the listed charge fees and acceptable bidding price for each biddable time slot? (2) what is the appropriate timing of the price markups and/or markdowns? and (3) to what extent, can we capture and measure customers' heterogeneous behaviours?

Several previous studies investigated different home delivery service strategies. Lin and Mahmassani compared both unattended and attended delivery policies for many online grocers with different settings of delivery time window durations (4). They claimed that providing the high level of service and convenience (in the form of specific and tight delivery time slots) desired by online customers often results in higher delivery costs, which directly affect the profitability of the operation. Boyer et al. examined the operational challenges involved in offering some value-added services to consumers (5), such as delivering groceries during a specified delivery window. The above studies find that the tighter service time window may attract more consumers, but the logistic difficulties are also severely increased.

Campbell and Savelsbergh developed methodologies for making order rejection/acceptance decisions to maximize expected profit (6). The key idea is to exploit information about potential future orders for evaluating whether it is better to accept a customer's order or to reserve capacity for potential future orders. They also resolved this tradeoff and examined the use of incentives to influence consumer behaviour to reduce delivery costs (7). The idea is sound; nevertheless, discriminating among customers based on specific rules and rejecting some customer's requests reduces customer satisfaction and may reduce future demand. Additionally, the uncertainties in predicting the 'potential future orders' may increase the failure probabilities of the actually future deliveries.

Some researchers applied dynamic programming in time slot management, but seldom dealt with customers' preferred delivery time requirement and price negotiation behaviour simultaneously. Reinartz developed a dynamic adjustment of prices to consumers depending on the value of a good or service (8). Different prices were charged to end consumers based on their discriminatory variables (i.e. similarly to concepts of willingness-to-pay).

Etzion et al. developed a model of the key trade-offs sellers face in such a dual-channel setting (i.e. selling identical products online using auctions and posted prices at the same time) built around the optimal choice of three design parameters: the posted price, the auction lot size, and the auction duration, as shown in Figure 1 (9). They claimed that incorporating an auction mechanism could yield 2.4% - 10% increases in revenue. The idea is interesting but customers may still want to pay the posted price for the low valuation products rather than bid for them directly. In addition, the 'valuation' may vary much among different customers. Caldentey and Vulcano (10) extended Etzion et al.'s model from deterministic to stochastic and to continuous time horizons.



**FIGURE 1 An Illustration of Dual Channel Settings (Etzion et al., 2006)**

The term “auction” was first defined by McAfee and McMillan, as the ‘a market institution with an explicit set of rules determining resource allocation and prices on the basis of bids from the market participants.’ (11) They also classified auction activities in four categories of the English auction (i.e. oral, open, and the ascending-bid auction,) the Dutch auction (i.e. the descending-bid auction,) the first-price sealed-bid auction, and the second-price sealed-bid auction. With the first-price sealed-bid auction, potential buyers submit sealed bids and the highest bidder is awarded the item or service for the price he places. The basic difference is that the bidders of the English auction could observe their competitors’ bids, but the first-price sealed-bid auction could not.

Lee and Szymanski et proposed a discriminatory price sealed bid (DPSB) auction mechanism (12). DPSB allows multiple bidders place their bids, and the price is accepted within the pre-determined pricing ranges. Table 1 shows the comparisons among above auction methods and the one applied in this study.

**TABLE 1 Comparisons among Different Auction Mechanisms**

	English Auction	Dutch Auction	First-price Sealed Bid Auction	Second-price Sealed Bid Auction	Discriminatory Price Sealed Bid Auction	Our Study
<b>Number of winners</b>	One	One	One	One	Many	Many
<b>Capacity constraint</b>	Yes	Yes	Yes	Yes	No	Yes
<b>Bidding method</b>	Open-cry	Open-cry	Sealed	Sealed	Sealed	Sealed
<b>Pricing</b>	The highest bidding price	The highest bidding price	The highest bidding price	The second highest price	Winners pay their bid price	Winners pay their bid price
<b>Example</b>	Antiques	Perishable commodities	Government contracts	The proxy bidding system	Dutch flower auctions	Attended delivery service

Stafford and Stern examined the motivations that drive consumer decisions to bid at on-line auction sites (13). They found that propensity to bid in on-line auctions is influenced by acceptance of technology, involvement with auctions, and affinity for computers. Bidders accept the technology and find it easy to use, possess a strong affinity with computers, and are highly involved with auction sites.



Popescu and Wu considered the dynamic pricing problem of a monopolist firm in a market with repeated interactions, where demand is sensitive to the firm's pricing history (14). They assumed that customers have memory and are prone to human decision-making biases and cognitive limitations. As the firm manipulates prices, consumers form a reservation price based on listed price perceptions.

Our method is improved from Kuo and Huang's dynamic pricing model (15). Kuo and Huang formulated a dynamic pricing model of a retailer selling products from two different generations (i.e. a dealer selling used and new cars), both with limited inventory over a predetermined selling horizon. However, customers could only consider one type of product each time. In addition, customers could negotiate one type of product only if they were unwilling to pay the posted price of another product. In our approach, we allow customers to consider multiple products (i.e. time slots) simultaneously. Three types of customers' behaviours (i.e. price-taker, price-negotiator, and leave-without-pay) are considered. For those price-takers, based on their locations and order characteristics (e.g. parcel sizes), the available time slots and corresponding reference prices are listed. If they decide to request a deliver time slot based on the listed price, then this request can be immediately accepted. However, if they are not satisfied with the offered prices, they can either negotiate the prices through bids or leave without any action. Those bids would be accepted if the capacity for each time slot  $i$  is available and the bidding price is higher than the minimum acceptable price.

#### **DEVELOPMENT OF THE SIMULATION-BASED DUAL CHANNEL MODEL**

In practice, the conventional delivery service providers tend to charge the fixed shipping fee which is not varied with the available delivery capacity, remaining time, and average customers' arrival rate in system. In our previous study (16), the posted shipping fee and the corresponding minimum acceptable price are optimized based on several dynamic pricing factors: the available capacity for each time slot  $i$  ( $\theta_i$ ), the remaining time before scheduling and dispatching trucks ( $t$ ), and average arrival rate ( $\lambda$ ). Our initial model has been reformulated and adapted into a simulation-based auction model to examine customers' heterogeneous preferences for different time slots, probabilities of transfer among time slots, and interactions between different posted and minimum acceptable bidding prices. All parameters and decision variables used in the formulation are listed below:

##### Sets

$I$  = a set of the delivery time slots;  
 $J$  = a set of the customers;  
 $S$  = a set of cargo parcel size.

##### Parameters and Inputs

$\theta_i^s$  : The available delivery capacity of parcel size  $s$  for the time slot  $i$ ;  
 $t$  : The remaining time periods before scheduling delivery;  
 $\lambda$  : The average customers' arrival rate;  
 $\pi_p$  : The total system expected revenue;  
 $\beta$  : The percentage of customers who are willing to bid;  
 $R_i^s$  : The average customers' reservation price of parcel size  $s$  for the time slot  $i$ ;  
 $\bar{F}(P_i^s)$  : The cumulative probability for customers with parcel size  $s$  reserving the time slot  $i$  with the listed shipping fee  $P_i$ ;  
 $F(P_i^s)$  : The cumulative probability for customers with parcel size  $s$  who balk at the listed shipping fee  $P_i$ ;  
 $\bar{F}(c_i^s)$  : The cumulative probability for a customer with parcel size  $s$  whose reservation price is between the posted shipping fee and the minimum acceptable price  $c_i$ ;  
 $F(c_i^s)$  : The cumulative probability for customers with parcel size  $s$  whose reservation price is even lower than the minimum acceptable price  $c_i$ .

### Decision Variables

$P_i^s$  : The listed shipping fee for the time slot  $i$ ;

$c_i^s$  : The service provider's minimum acceptable price for the time slot  $i$ ;

$x_{ij}^s$  : A binary integer variable if the time slot  $i$  with parcel size  $s$  is assigned to the price-

taker customer  $j$  ( $x_{ij}^s = 1$ ) and 0 otherwise;

$y_{ij}^s$  : A binary integer variable if the time slot  $i$  with parcel size  $s$  is assigned to the price-

bidder customer  $j$  ( $y_{ij}^s = 1$ ) and 0 otherwise.

### Model Formulations

Here we assume that customers can simultaneously consider multiple time slots based on the listed shipping fees determined by service providers. In order to consider the characteristics of different time slots, we assume that two types of time slot settings are introduced, where  $\theta_i^s$  and  $\theta_{i'}^s$  represent the available delivery capacity for time slots  $i$  and  $i'$ , respectively. If customers prefer the time slot  $i$  over slot  $i'$ , the posted shipping fee of slot  $i$  is higher initially.

$$\begin{aligned}
 \pi_p(P_i^s, P_{i'}^s, \theta_i^s, \theta_{i'}^s, t) &= \max_{P_i^s, P_{i'}^s, i \neq i'} V_p(P_i^s, P_{i'}^s, \theta_i^s, \theta_{i'}^s, t) \\
 &= \lambda(1-\beta_1)\bar{F}(P_i^s) \left[ P_i^s + \pi_p(\theta_i^s - 1, \theta_{i'}^s, t-1) \right] \\
 &\quad + \lambda(1-\beta_1)F(P_i^s)(1-\beta_2)\bar{F}(P_{i'}^s) \left[ P_{i'}^s + \pi_p(\theta_{i'}^s - 1, \theta_i^s, t-1) \right] \\
 &\quad + \lambda(1-\beta_1)F(P_i^s)\beta_2 \left\{ \int_{P_i^s}^{R_i^s} [\alpha P_i^s + (1-\alpha)c_i^s] f(x)dx \right. \\
 &\quad \left. + \int_{c_i^s}^{P_i^s} [\alpha P_i^s + (1-\alpha)c_i^s] f(x)dx + \bar{F}(c_i^s) \times \pi_p(\theta_i^s, \theta_{i'}^s - 1, t-1) \right\} \\
 &\quad + \lambda\beta_1 \left\{ \int_{P_i^s}^{R_i^s} [\alpha P_i^s + (1-\alpha)c_i^s] f(x)dx + \int_{c_i^s}^{P_i^s} [\alpha P_i^s + (1-\alpha)c_i^s] f(x)dx + \bar{F}(c_i^s) \pi_p(\theta_i^s - 1, \theta_{i'}^s, t-1) \right\} \\
 &\quad + \lambda\beta_1 F(c_i^s)(1-\beta_3)\bar{F}(P_{i'}^s) \left[ P_{i'}^s + \pi_p(\theta_{i'}^s, \theta_i^s - 1, t-1) \right] \\
 &\quad + \lambda\beta_1 F(c_i^s)\beta_3 \left\{ \int_{P_{i'}^s}^{R_{i'}^s} [\alpha P_{i'}^s + (1-\alpha)c_{i'}^s] f(x)dx + \int_{c_{i'}^s}^{P_{i'}^s} [\alpha P_{i'}^s + (1-\alpha)c_{i'}^s] f(x)dx + \bar{F}(c_{i'}^s) \pi_p(\theta_{i'}^s, \theta_i^s - 1, t-1) \right\} \\
 &\quad + \left\{ 1 - \lambda \left[ (1-\beta_1) \left[ \bar{F}(P_i^s) + (1-\beta_2)F(P_i^s)\bar{F}(P_{i'}^s) + \beta_2F(P_i^s)\bar{F}(c_{i'}^s) \right] \right. \right. \\
 &\quad \left. \left. - \beta_1 \left[ \bar{F}(c_i^s) + (1-\beta_3)F(c_i^s)\bar{F}(P_{i'}^s) + \beta_3F(c_i^s)\bar{F}(c_{i'}^s) \right] \right] \right\} \pi_p(\theta_i^s, \theta_{i'}^s, t-1) \\
 &\quad \forall i, i' \in I, i \neq i', \forall j \in J, \forall s \in S
 \end{aligned} \tag{1}$$

For those customers entering the system, seven outcomes are expressed in Equations 1: (1) customer is a price-taker and prefers time slot  $i$ ; (2) customer is a price-taker and prefers time slot  $i$ , but his reservation price is below the reference price  $P_i^s$  and above  $P_{i'}^s$ ; (3) customer is a price-taker whose reservation price is between the posted shipping fee and the minimum acceptable price for both time slots; (4) customer is a bidder and only wants time slot  $i$ ; (5) customer is a bidder and prefers time slot  $i$ , but his reservation price is below the reference price  $P_i^s$  and above  $P_{i'}^s$ ; (6) customer is a bidder whose reservation price is between the posted shipping fee and the minimum acceptable price for both time slots; (7) customer leaves without any action.

The opportunity cost function (i.e. cost difference between assigning and not assigning time slot  $i$ , which also implies the minimum acceptable price) is specified in Equations 2 and 3. Finally, the boundary conditions are stated in Equations 5 and 6.

$$c_i^s = \pi_p(\theta_i^s, \theta_i^s, t-1) - \pi_p(\theta_i^s - 1, \theta_i^s, t-1) \quad (2)$$

$$c_i^s = \pi_p(\theta_i^s, \theta_i^s, t-1) - \pi_p(\theta_i^s, \theta_i^s - 1, t-1) \quad (3)$$

$$\pi_p(\theta_i^s, \theta_i^s, t=0)=0 \quad \text{for } \theta_i^s, \theta_i^s \geq 0 \quad (4)$$

$$\pi_p(\theta_i^s = \theta_i^s = 0, t)=0 \quad \text{for } t=1, \dots, T \quad (5)$$

Traditionally, optimization models have been viewed as normative techniques while simulation frameworks are commonly used to evaluate the performance of optimization models, describe a complex system, or perform sensitivity analyses. However, there exist some interrelations between optimization and simulation models in which both are used to produce feasible and attainable solutions. These tools offer a powerful framework from which to approach complex problems and obtain superior performance solutions (17).

In accordance with the posted shipping fee and the corresponding minimum acceptable price optimized above, one optimization model is further developed for determining which time slot should be assigned to which customer during the simulation phases.

$$\text{Maximize } \omega_p = \sum_i \sum_{i,i \neq j} \sum_j \sum_s P_i^s x_{ij}^s + \max(R_i^s, c_i^s) y_{ij}^s + P_i^s x_{ij}^s + \max(R_i^s, c_i^s) y_{ij}^s \quad (6)$$

Subject to

$$x_{ij}^s + y_{ij}^s + x_{ij}^s + y_{ij}^s \leq 1 \quad (7)$$

$$\sum_j (x_{ij}^s + y_{ij}^s) \leq \theta_{ij}^s \quad (8)$$

$$\sum_j (x_{ij}^s + y_{ij}^s) \leq \theta_{ij}^s \quad (9)$$

$$x_{ij}^s \in (0,1) \quad y_{ij}^s \in (0,1) \quad (10)$$

The objective function (Equation 6) is derived from the maximization of total system revenue ( $\omega_p$ ) by either price-takers' or bidders' time slot assignment results. Equation 7 specifies that at most one time slot can be assigned to an identical customer. Equations 8 and 9 express the capacity constraints for time slots. Equation 10 denotes the binary integer decision variables in this model.

## APPLICATION OF MODELS AND COMPUTATIONAL RESULTS

Through this simulation we seek to consider multiple factors in a system for allocating delivery time slots in time-dependent, stochastic and dynamic environments. Random customers' reservation prices, different probabilities of choosing time slots, the willingness (in terms of probability) of re-bid, the transfer probability to other slots if the capacity of customer's most desired slot is reached, and different customers arrival patterns are considered in this simulation system and coded with the software *Arena* 14.

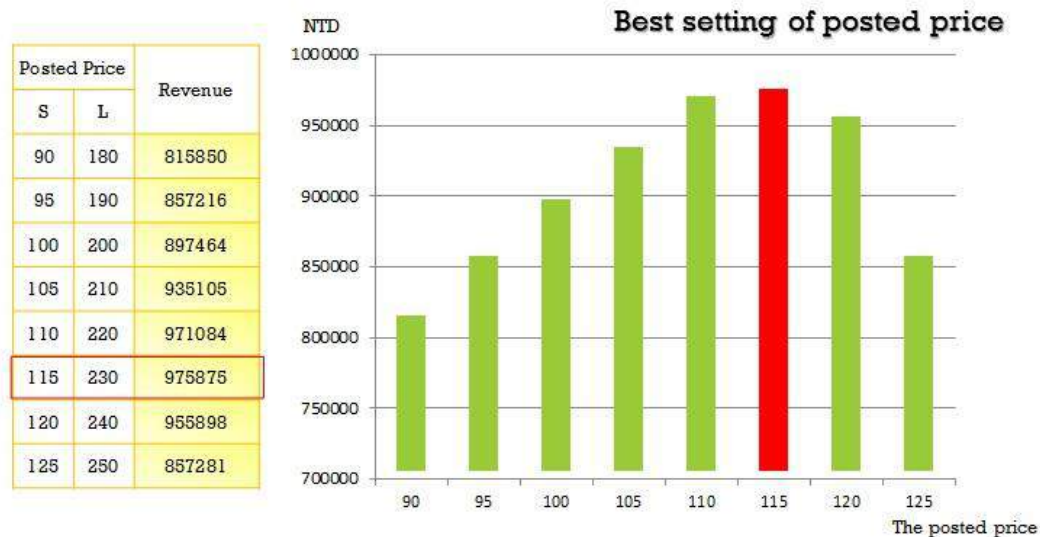
In this study we first develop a general model, but those formulations could be further revised for certain specific products, such as perishable cargos in cold-chain logistics with nonlinear time-dependent value settings. Some applications arise when the service time slots have significantly different demand. Additionally, this study provides flexibility for

behaviourally-realistic decision rules among customers and attended home delivery logistics service providers. Four different time slots ( $\tau_1$ ,  $\tau_2$ ,  $\tau_3$ , and  $\tau_4$ ) are assumed in this study. Most input parameters were generated through extensive consultation with our industrial partners to closely replicate real data in Taiwan, R.O.C.

### Different Initial Posted Shipping Fee

The posted shipping fee ( $P^s_i$ ) is one main factor directly affected the total system revenue ( $\omega_p$ ). In accordance with our previous study (15), the optimal posted shipping fees of small and large parcels are 115 and 230 NTD, respectively. Figure 3 shows the results of sensitivity analysis for different posted pricing levels. Here we assume that initial posted shipping fees of four different time slots are the same (i.e. the baseline setting in Table 2.)

The illustrated results show that the total system revenue during the lower posted price settings are relatively low, but higher posted price settings may yield diminishing revenue due to lower successful time slot assigned rates for price-takers.



**FIGURE 2 Total System Revenue under Different Posted Price Settings**

### CONCLUSIONS

Managerial interest in the bidder segment rests on the attractiveness of a rapidly growing pool of potential new customers. We suggest that logistics service providers can consider our auction models if high percentages of their customers are willingness to negotiate price. Our main purpose is to explore the feasibility of introducing the dynamic pricing concept and auction behaviour into the attended home delivery service, starting from the assumption that a fraction of customers would be attracted to the time slots open for selecting and/or bidding.

Although these assumptions and tested case studies could be extended with greater complexity and realism, such analysis provides a basis for future refined auction models, which should involve the more complicated interrelation between customers' choice behaviours and different pricing strategies by transferring certain peak delivery requests to the off-peak time slots. In addition, a heuristic algorithm might be required for future real-time operations.

### ACKNOWLEDGMENTS

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# SIMULATION ANALYSIS OF VMI VS CPFR IN RETAILER PROMOTIONS<sup>1</sup>

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## Abstract

### Purpose of this paper

There is much anecdotal evidence of the successes of VMI (Vendor Managed Inventory) and of CPFR (Collaborative Planning, Forecasting and Replenishment). There are also examples where one or both of these approaches has disappointed. The present paper compares VMI and CPFR to each other, and to a base case, IS (Independent Sourcing). With a retailer promotion, demand can change by quite a bit from its usual values. Importance of sharing information in the forecasting and communication processes is thus highlighted.

### Design/Methodology/Approach

A discrete-event simulation model is constructed. Regular and promotional demand data for several consumer and industrial products are available from 3M Canada. The technique of "Common Random Numbers" is employed to reduce the variance of the simulated results.

### Findings

When demand is steady, i.e. without promotions, CPFR and VMI perform comparably. In the case of a large, seasonal promotion, it is found that both the costs and also the inventories of CPFR are statistically-significantly lower than those in VMI and IS.

### Originality/Value

Few papers study effectiveness of VMI or CPFR for *retailer promotions*. VMI and CPFR imply certain differences: inventory policies, degrees of information sharing, communication on the timing of promotions. Our simulations, based on real-world data, show the importance of sharing the *right* information, and of clearly conveying its meaning to supply chain partners.

### Keywords

Inventory, simulation, promotions, VMI, CPFR

### Paper Type

Research Paper

### References

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Panahifar, F., Heavey, C., Byrne, P.J., and Fazlollahtabar, H., 2015. A framework for Collaborative Planning, Forecasting and Replenishment (CPFR): State of the Art. *Journal of Enterprise Information Management*, 28 (6), 838-871.

## INTRODUCTION

To increase demand, retailers utilize promotional activities such as coupons, advertising, and especially price discounts. However, a promotion mismanaged can negate potential gains: stockouts during a promotion cause customer dissatisfaction. A particular survey estimated that only 35% of manufacturers' promotions were profitable.

A promotion's effectiveness may be enhanced when supply chain partners share information. That sharing may also enable reduced inventory levels, improved demand forecasts, and decreased costs. Companies such as Wal-Mart and Proctor and Gamble have implemented the popular programs VMI (Vendor Managed Inventory) and CPFR (Collaborative Planning, Forecasting, Replenishment) with positive results (Waller et al., 1999; Steermann, 2003). The VMI vendor initiates orders for the retailer. The VMI vendor thus manages the retailer's stocks, facilitated by receiving retailer's point-of-sale (POS) and inventory data. With VMI, vendor's decisions can be based on actual sales.

Developed in the 1980s, VMI has been utilized by Campbell Soup and Johnson & Johnson (Waller et al., 1999). In CPFR, supply chain members exchange information impacting future demand. By consolidating the intelligence of all participating firms, CPFR promises to improve demand forecast accuracy, hence reduce inventory levels, increase fill rates, and decrease lead times. Partners interact and combine business and promotional plans, to create a *joint* business plan. Then, forecasts of sales and orders are developed together.

With additional information sharing, expending greater resources than VMI, CPFR is said to be more effective at addressing changing demand patterns and improving costs. Using CPFR, Heineken cut forecast error by 15%, Michelin improved fill rates by 11%; Motorola reduced inventory by 30% (Hill & Mathur, 1999; Steermann, 2003; Cederlund et al. 2007).

Can the preceding approaches also improve the effectiveness of promotional activities? Less information is shared in VMI than CPFR; what are the consequences during promotions? Via simulation, we examine how VMI and CPFR handle "promotional demand," i.e., cases where demand increases rapidly over a short time. For a three-stage supply chain of a single item facing stochastic demands, we compare promotional demand patterns to a steady one with no promotions as a base case. Different demand variability and target fill rates were tested. The simulation was validated and run using empirical sales data from 3M Canada.

## BRIEF LITERATURE REVIEW

Waller et al. (1999) simulated a two-stage supply chain, finding that stock level dropped and production was smoothed with VMI. Others have suggested that VMI performs poorly during promotions (Aichlmayer, 2000). A detailed study of this assertion is our main purpose here.

Sari (2007) found that VMI performance dropped as demand uncertainty increased, concluding that the vendor needs additional data to resolve that uncertainty. CPFR promises to address the preceding issues. Sales forecasts should be jointly created, so vendors are no longer surprised by the retailer's marketing activities (Aichlmayer, 2000). However, Sari (2008) inferred, via a simulation model, that for short lead times, or tight manufacturing capacity, benefits of CPFR and VMI were less distinguishable.

Mangiaracina et al. (2012) show the pluses and minuses of VMI in the grocery supply chain. More generally, for the *food* supply chain, Eksoz et al. (2014) present a collaborative-

forecasting framework. They emphasize information sharing and supply chain integration. Thomé et al. (2014) focus on the business processes involved in CPFR.

Several references cited above determine that VMI enables improvements in supply chain costs and profits. However, such conclusions for the retailer, vendor, and the two party supply chain may pertain only to particular choices of the model parameters. Bookbinder et al. (2010) give a number of examples in which VMI may benefit both parties, or only the retailer, or only the vendor, or neither member of the supply chain.

Kamalapur and Lyth (2014) perform a CPFR simulation, stressing additional details at vendor  $V$  and retailer  $R$ . That paper, and others using simulation to study VMI and/or CPFR and compare to a traditional, IS supply chain, differ from our research in one or more ways:

- Only one of VMI or CPFR is compared to IS. We compare all three.
- We consider retailer service (fill rate  $P_2$ ), not just the cost at each node
- The mechanics of CPFR may not be the same, e.g. in the way that the collaborative forecast is prepared. (The forecast is assumed to be *jointly* prepared in our model.)
- Certain details of the simulation logic may contrast with ours. (See Table 1, below, for the business conditions or assumptions of each our simulation models.)

Others have examined demand fluctuations in CPFR and VMI; no authors have tackled extreme demand swings occurring during *promotion* of a consumer product. The empirical 3M data contained some demands which could double, even triple, during a promotion.

## MODEL DESCRIPTION

We modeled a three-tier supply chain (retailer, vendor, manufacturer) on a weekly basis. A simulated CPFR implementation between the retailer  $R$  and vendor  $V$  was compared to a VMI arrangement between  $R$  and  $V$ , and to IS. A retailer stockout resulted in lost sales; stockouts at vendor level were backordered.  $V$  placed orders with the manufacturer, who was assumed to have unlimited supply, hence could fulfill vendor's orders with enough lead time. This supposition (unlimited supply) was made so as to "end" the supply chain. But even with unlimited stock at manufacturer,  $V$  could still experience outages if its forecasts were wrong.

In IS, the base case, the vendor's own demand forecast cannot distinguish between orders placed for "regular" demand and those for upcoming retailer promotions. That is because, in IS,  $R$  and  $V$  share no information. In VMI, the vendor does receive retailer's POS and inventory data. However,  $R$  shares only *some* demand information with  $V$ . The vendor in VMI knows that promotions will occur, but not when.

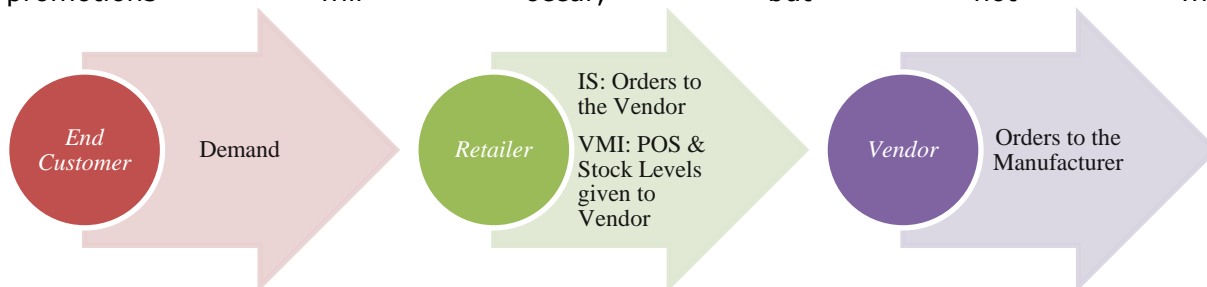


Figure 1: Flow of Information through the Supply Chain in IS and VMI

The retailer and vendor in CPFR create a single forecast and confide with each other the promotional plans, POS data, and inventory data. Absent promotions, retailer information shared with the vendor in CPFR does not differ from information shared with vendor in VMI. Advantages of CPFR over VMI come when the retailer  $R$  can offer information that the vendor



cannot deduce from either inventory or POS data. (Here, this unique information comes from prior knowledge of *promotions*.) Another advantage comes from collaborating on the replenishment plan. *V* may slightly adjust the order from *R*, to prevent backorders.

Figures 1 and 2 contrast the information flows in IS, VMI, CPFR. Table 1 compares particular assumptions in simulating each of those strategies. That table details the issues concerning forecasting, replenishment policies, and the impacts of stockouts and promotions.

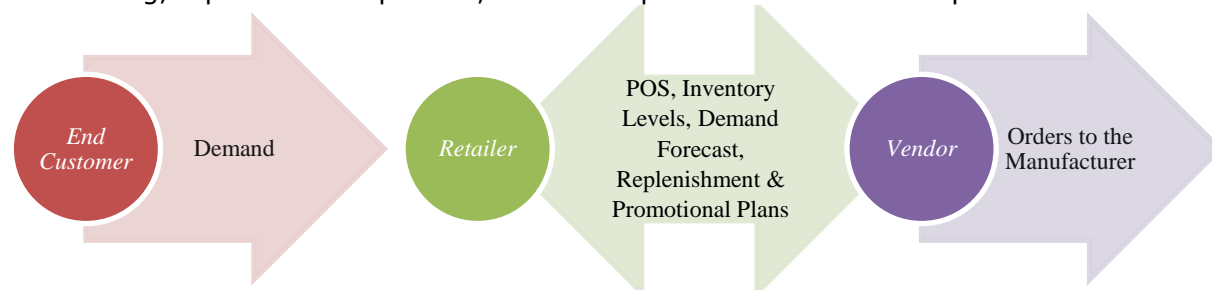


Figure 2: Flow of Information through the Supply Chain in CPFR

### Some Simulation Details

Two scenarios were created, one with retailer-determined promotions and one with none. In the latter, the weekly demand distribution was the same all year. Inventory policies aimed to eliminate stockouts at the vendor. Stockouts at the retailer would thus occur only because of its own errors in forecasting.

In the case with promotions, a two-week promotional period took place every quarter with mean demand remaining steady during non-promotion weeks. Timing of each promotion was determined randomly, to ensure that in IS and VMI, only the retailer would know when promotions would occur. The VMI vendor knew a promotion would take place each quarter, but would be informed by the retailer of its timing only one week prior. This gave the vendor enough opportunity to ship additional inventory, provided it was available. Therefore, it was the vendor's policy to order extra anticipation stock at the start of each quarter.

### Simulating with Empirical Data from 3M

Empirical weekly sales data were furnished by 3M Canada from four product categories: first aid, home care, stationary, and hardware. Attempts to fit a distribution to the provided demand data were unsuccessful. (No distribution had a P-Value > 0.5; Kolmogorov-Smirnov test.) Demand was thus simulated from normal distributions, with the observed  $\mu$  and  $\sigma$ .

Since cost parameters were not provided by 3M, exchange curves were employed. We looked for ratios of the ordering cost to carrying cost ( $K/r$ ) that would produce reasonable order times and quantities. Below, the term *Scenario* means specific  $K/r$  ratios and lead times for the simulations. Along with a lower  $K/r$  ratio, items or products in Scenario 1 had shorter lead times: one week at vendor, two weeks at the manufacturer. Products in Scenario 2 had lead times of two weeks at vendor, four weeks at manufacturer. For each Scenario, an item exhibiting steady demand, one with several demand spikes, and one with a large spike in demand, were selected (Fig. 3). Products chosen for "demand without promotions" (3M-Products A and B), and those selected for "demand with promotions" (termed Products C and D), and all demand parameters, are in Table 2.

Table 1: Business Conditions for IS, VMI, and CPFR Simulations

	Retailer <i>R</i>			Vendor <i>V</i>			Manufacturer
	IS	VMI	CPFR	IS	VMI	CPFR	

Forecasting	A	A	B	C	D	B	
Inventory Policy and Ordering	E	F	G	H	F	G	
Stockouts	lost sale			back-order			none (Assumption of unlimited supply)
Information Sharing	<i>R</i> receives no info from <i>V</i>	I	J	<i>V</i> receives no info from <i>R</i>	I	J	
Promotions (Timing is Random in every case, one promotion per quarter.)	K	L	M	K	L	M	

#### Legend

- A Retailer (IS or VMI) forecasts end-customer demand: exponential smoothing,  $\alpha = 0.1$ .
- B Single, shared CPFR forecast between *V* and *R*, based on latter's promotional plans.
- C IS vendor makes its own demand forecast (also using exponential smoothing with  $\alpha = 0.1$ ), based just on the orders received intermittently from retailer.
- D VMI vendor forecasts based on retailer's POS info on sales and inventory ( $\alpha = 0.1$ ).
- E IS retailer orders are based on its desired fill rate.
- F VMI retailer sets order point to attain desired fill rate; *V* places orders for *R*.
- G If Vendor is short by  $< 10\%$  of a retailer's order, that replenishment quantity is adjusted downward, to prevent back-orders and related penalties.
- H IS vendor orders by POQ (Period Order Quantity).
- I *R* gives POS and inventory info to *V* in VMI.
- J *V* & *R* collaborate on replenishment plan in CPFR.
- K No advanced knowledge given by *R* to *V*.
- L *V* is informed by *R* only 1 week in advance of promotion.
- M At the start of each quarter *V* is informed by *R* of the precise timing of a promotion, and of its anticipated impact on demand.

A stationary item (3M Product E) was selected to model Scenario 1 in simulations with one large, seasonal promotion (Table 3). During most of the year, mean weekly demand was 88 and standard deviation 33. Product E had a longer holiday season (14 weeks) and short lead times, so retailer placed *weekly* orders in that season. As the holidays progressed, retailer's demand forecasts were assumed to improve, with more information on customers' reactions.

The second scenario concerns a 3M hardware item, termed Product F (Table 3). Demand for most weeks had a mean of 972 and standard deviation 261. In Scenario 2, lead times are longer, and due to a shorter (seven-week) holiday season, weekly replenishments would be fruitless. Longer lead times prevent learning from recent demands. For VMI and CPFR, vendors must place their orders *before* the holiday season. Hence, rather than ordering weekly, a retailer of Product F *orders* once for the holiday season, just prior to its start.

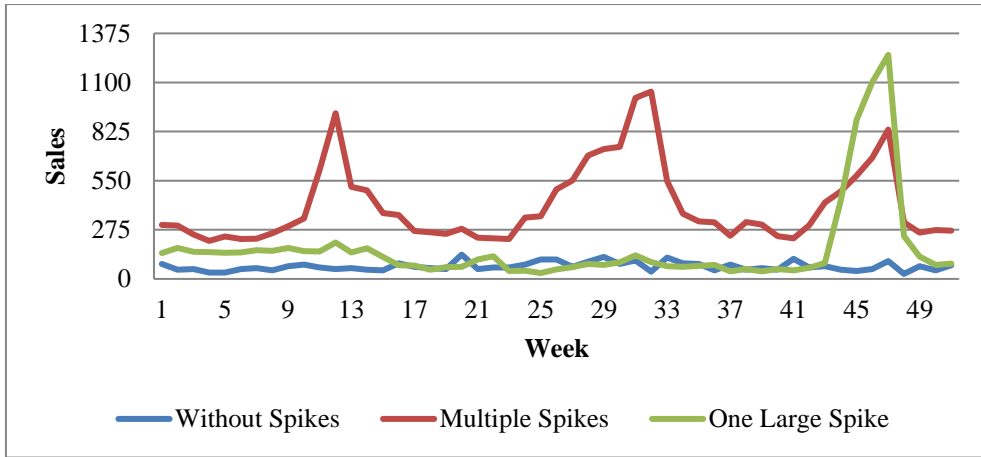


Figure 3: The Three Patterns of Annual Demand. These correspond respectively to Products A and B; Products C and D; and Products E and F.

Table 2: Demand Parameters for Empirical Data: 3M Products A, B, C & D

Product	Scenario	Product Category	Demand Type	Weekly Demand Mean	Weekly Demand Standard Deviation
A	1	First Aid	Regular	72	24
B	2	Home Care	Regular	2518	278
C	1	Stationary	Regular	213	54
			Promotional	590	213
D	2	Hardware	Regular	306	89
			Promotional	949	275

To capture different intensities of retailer promotions, three demand peaks (Table 3) were created. If the retailer aggressively promoted the product during the holiday season, the demand peak increased. If  $R$  did not promote the item during that season, the peak decreased. Demands during weeks leading up to and after peaks were scaled accordingly.

A steady state simulation was run, usually for 676 weeks, deleting the first 156 weeks to remove transient effects. (This very conservative warm-up period ensured that no initial transients were included in results of the various simulations.) Target fill rates of 95% and 99% were tested. The replication-deletion approach was employed, as it gives good statistical performance (Law, 2014). 2000 replications were run for each scenario and every target fill rate. To reduce variance, the technique of common random numbers was applied.

Table 3: Demand Parameters used in Simulations with One Large, Seasonal Promotion

3M Product	Scenario & Category	Demand Parameters	Promotional Plan		
			No Promotions	Regular Promotions	Aggressive Promotions
E	1: Stationary	Mean	42926	85852	128778
		Standard Deviation	17067	34135	51202
F	2: Hardware	Mean	10222	12778	15333
		Standard Deviation	2745	3431	4117

## SIMULATION RESULTS

90% confidence intervals for simulated differences in system-wide costs between IS, VMI, and CPFR were found. "Costs" are the sum of holding plus ordering costs over the full run. For both Products A and B, IS had the highest system-wide costs and the greatest system stocks for each P2 target (95%, 99%). VMI and CPFR had similar system-wide costs and inventory levels; both were lower than IS. Table 4 presents confidence intervals for costs.

Table 4: Confidence Intervals for the Difference in System-Wide Costs: 3M Products A and B

Product	Target Fill Rate (%)	Confidence Interval: Cost Differences (\$ Thousands)		
		IS - VMI	IS - CPFR	VMI - CPFR
A	95	(0.33, 1.11)	(0.34, 1.10)	(-0.07, 0.06)
	99	(0.57, 1.21)	(0.57, 1.21)	(-0.09, 0.07)
B	95	(11.93, 16.13)	(11.97, 16.05)	(-0.60, 0.55)
	99	(11.62, 16.53)	(11.90, 16.44)	(-1.15, 1.15)

IS had greatest system-wide costs and the largest system-stocks of both Products C and D. VMI ranked second in system costs and inventory levels; CPFR was best in each category. Confidence intervals confirmed significant differences in system-wide costs and inventories between IS, VMI, CPFR (Table 5).

Table 5: Confidence Intervals for the Difference in System-Wide Costs: 3M Products C and D

Product	Target Fill Rate (%)	Confidence Intervals: Cost Differences (\$ Thousands)		
		IS - VMI	IS - CPFR	VMI - CPFR
C	95	(2.12, 2.65)	(3.15, 3.67)	(0.85, 1.19)
	99	(2.68, 3.30)	(3.97, 4.55)	(1.04, 1.52)
D	95	(2.00, 4.04)	(4.27, 6.12)	(1.46, 2.83)
	99	(1.82, 3.97)	(5.05, 7.18)	(2.34, 4.10)

In simulations with one large promotion (Table 6), at 95% P2 target, the IS supply chain for Product E had the greatest costs. But at higher P2 target, 99%, there was no statistically significant difference between system-wide costs of IS and VMI. For both target fill rates, CPFR had the lowest system-wide costs. There was no statistically significant difference between system-wide costs of VMI and IS for Product F (Table 7). Confidence intervals show the CPFR system-wide costs as lowest of the three approaches. Inventory results are similar to cost results: CPFR had statistically significant drops in supply-chain *stocks* vs IS and VMI.

Table 6: Confidence Intervals for the Difference in System-Wide Costs: 3M Product E

Target Fill Rate (%)	Confidence Intervals: Cost Differences (\$ Millions)		
	IS - VMI	IS - CPFR	VMI - CPFR
95	(0.27, 0.76)	(0.90, 1.22)	(0.20, 0.90)
99	(-0.39, 0.24)	(0.79, 1.27)	(0.63, 1.58)

Table 7: Confidence Intervals for the Difference in System-Wide Costs: 3M Product F

Target Fill Rate (%)	Confidence Intervals: Cost Differences (\$ Thousands)		
	IS - VMI	IS - CPFR	VMI - CPFR
95	(-29.77, 14.41)	(16.45, 35.78)	(3.74, 63.75)
99	(-60.23, 39.45)	(31.94, 129.48)	(4.52, 162.06)

## ANALYSIS AND DISCUSSION

In situations of steady demand (e.g. Products A and B), with no large increases expected, CPFR and VMI can perform comparably (Table 4). These results were anticipated, as the degree of information sharing in VMI and CPFR is similar. For multiple promotions, VMI did lower operating costs vs IS for both Products C and D, Table 5. In Fig. 3, some 3M-demand patterns were highly variable. For simulations run under those conditions, confidence intervals for all cases shifted in a positive direction. (Compare the IS-CPFR and VMI-CPFR columns in Table 7, with respective columns in Table 5.) This indicates that information-sharing methodologies become more advantageous at greater levels of demand variability.

CPFR was able to provide additional reductions, relative to VMI, in costs and in supply chain inventories. These results were statistically significant. Performance differences between VMI and CPFR are particularly apparent for large seasonal promotions (Table 7), when product's annual sales occur mostly within a brief period. Though able to furnish benefits for smaller promotions during the year, VMI struggled to reduce operating costs and stock levels for Products E and (especially) F. For these items, VMI provided statistically significant cost reductions in only one case (Table 6).

For one large seasonal promotion, simulated CPFR system-wide costs and inventories were lower than in VMI and IS (Tables 6, 7). A supply chain facing rapidly varying demands needs complete information sharing; VMI offers too little information to forecast these variations.

## CONCLUSIONS AND FURTHER RESEARCH

This paper has examined how information sharing could improve the effectiveness of *promotional programs*. A simulation study of a three-stage supply chain was devised. CPFR was compared to Vendor Managed Inventory (VMI; supplier initiates orders on behalf of buyer, obtaining the latter's sales and inventory information), and to Independent Sourcing (IS; no information exchanged; each supply-chain member is on its own). The simulation model was validated and run with empirical data from 3M Canada.

The *timing* of demand promotions was shared with the vendor only in CPFR (see Table 1), not with the vendor in VMI. To achieve the targeted fill rates, the VMI vendor thus had to hold more stock, incurring greater costs than in CPFR. When demand is steady, i.e. without promotions, CPFR and VMI perform comparably (Table 4). However, when promotions cause greater increases in demand, as in large seasonal promotions for products E, F (Table 3), VMI becomes less effective. Indeed, for that large single promotion, VMI sometimes cannot produce better results than when no information is shared (Tables 6 and 7). With a single, large seasonal promotion, the latter tables note that costs (and also inventories; not shown) of CPFR are statistically-significantly lower than those in VMI and IS. With only POS and inventory data, a VMI vendor cannot predict a promotion's timing, nor impact on sales.

More information is shared in CPFR. Collaboration includes promotional magnitudes and timings; the vendor is not caught off guard by promotions and thus can better serve the retailer's needs. Firms wishing to improve the efficacy of promotional programs must be willing to part with data that can help supply-chain partners prepare for such events.

We would like to run the simulation with demand distributions beyond those of Fig. 3, including non-stationary demands. Consideration of chains with additional retailers would be helpful to a vendor serving multiple customers. That vendor may find CPFR to be of even greater value, if promotions at different retailers are likely to occur at the same time, as may be true for seasonal demands.

# MODELS AND HEURISTICS FOR THE FLOW-REFUELLING LOCATION PROBLEM

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## ABSTRACT

**Purpose of this paper:** Firstly, the paper serves as an overview of the emerging field of flow-refuelling location, which mainly occurs in the context of locating alternative-fuel (hydrogen, electric, liquefied natural gas and hybrid) vehicle refuelling stations. We aim to review and explain models and solution approaches, with a particular focus on mathematical programming formulations. Secondly, we propose a new heuristic for this problem and investigate its performance.

**Design/methodology/approach:** The subject scope of this paper is the flow-refuelling location model (FRLM). While in most location problems demand arises at customer locations, in so-called flow-capturing models it is associated with journeys (origin-destination pairs). What makes the FRLM even more challenging is that due to the limited driving range of alternative-fuel vehicles, more than one facility may be required to satisfy the demand of a journey. There are currently very few such refuelling stations, but ambitious plans exist for massive development – making this an especially ripe time for researchers to investigate this problem. There already exists a body of work on this problem; however different authors make different model assumptions, making comparison difficult. For example, in some models facilities must lie on the shortest route from origin to destination, while in others detours are allowed. We aim to highlight difference in models in our review. Our proposed methodology is built on the idea of solving the relaxation of the mixed-integer linear programming formulation of the problem, identifying promising variables, fixing their values and solving the resulting (so-called restricted) problems optimally. It is somewhat similar to Kernel Search which has recently gained popularity. We also use a parallel computing strategy to simultaneously solve a number of restricted problems with less computation effort for large-sized instances.

**Findings:** Our experimental results show that the proposed heuristic can find optimal solutions in a reasonable amount of time, outperforming other heuristics from the literature.

**Value:** We believe the paper is of value to both academics and practitioners. The review should help researchers new to this field to orient themselves in the maze of different problem versions, while helping practitioners identify models and approaches applicable to their particular problem. The heuristic proposed can be directly used by practitioners; we hope it will spark further works on this area of logistics but also on other optimisation problems where Kernel Search type methods can be applied.

**Research limitations:** This being the first paper applying a restricted-subproblem approach to this problem it is necessarily limited in scope. Applying a traditional Kernel Search method would be an interesting next step. The proposed heuristic should also be extended to cover for more than just one FRLM model: certainly the capacitated FRLM, the FRLM with deviation, the fixed-charge FRLM and the multi-period FRLM should be investigated.

**Practical implications:** Our work adds to a body of research that can inform decision-makers at governmental or international level on strategic decisions relating to the establishment or development of alternative-fuel refuelling station networks.

## INTRODUCTION

The flow-refuelling location problem is a logistics problem that mainly occurs in the context of locating alternative-fuel (hydrogen, electric, liquefied natural gas and hybrid) vehicle refuelling stations. Alternative-fuel station location is a recent, but very applicable research topic within logistics. In essence, what make the problem of determining locations of alternative-fuel refuelling stations different from those of petrol stations is the scarcity of current infrastructure. In fact, alternative-fuel vehicles require a very dense refuelling infrastructure, as these vehicle typically have a short driving range. The alternative-fuel industry is suffering from a "vicious circle": there is little appetite for infrastructure investment as there are not a sufficient number of alternative-fuel vehicles, the automotive industry can only produce these vehicles at high process as there are not sufficient economies of scales due to limited demand, and customers are discouraged from buying such vehicles due to both their price and the limited refuelling infrastructure. This topic is especially timely in the light of the recent European directive requiring Member States to provide a minimum coverage of refuelling points for alternative fuels (European Commission, 2014). The directive provides a regulatory framework for alternative fuels such as hydrogen, electricity, liquefied natural gas and compressed natural gas. The targets are very ambitious. Compressed natural gas stations and hydrogen stations are to be built along the European TEN-T core network at intervals of 400 and 300 kilometres, respectively. The electricity refuelling network is to be multiplied significantly, from about 12,000 to 800,000 charging stations. Thus, this is the right time for Logistics researchers to devote their energies to finding optimal or near-optimal locations for alternative-fuel refuelling facilities.

We first review the literature of this problem, including the mathematical models proposed. Then, we present our new heuristic algorithm and show our numerical experimentation with it. Finally, a brief summary and ideas for future research are given.

## LITERATURE REVIEW

The flow-refuelling location model (FRLM), introduced by Kuby and Lim (2005), has its origins in the flow-capturing location model (FCLM) of Hodgson (1990). This model is based on the concept of "locating facilities on the home-to-work journey" and the observation that in some cases it makes more sense to locate facilities near routes that customers already take. The author showed that basing locational decisions simply on arc flow volumes is not sufficient; instead, models should be based on detailed origin-destination flow data. An important aspect of the FCLM is that any flow (origin-destination pair) is captured by a single facility. This is sensible as one would not, for example, stop at every roadside supermarket on the way home, one stop is sufficient to satisfy one's shopping needs.

The main difference of the FRLM from the FCLM is that a single facility may be unable to capture an entire flow. This is due to the issue of "limited range", namely, that a vehicle may not be able to undertake a given origin-destination journey with a single refuelling stop. This model is most applicable to vehicles powered by alternative fuels, such as

hydrogen or electricity. Such vehicles normally can cover a shorter distance on a full tank than traditional gas-guzzling vehicles. In addition, the availability of alternative fuel refuelling stations is very limited. However, the model is also applicable to the location of conventional refuelling stations in developing countries where infrastructure is as yet lacking. Likewise, it can be applicable to territories with sparse population (and hence sparse refuelling infrastructure).

Kuby and Lim (2005) introduced the FRLM, motivating the new model with the above concept of vehicle range. They observe that origin-destination data, rather than simple traffic count on edges, is required to model this problem properly. Multiple facilities may be required to serve individual journeys. Unlike in the FCLM, it can be shown that it is not sufficient to consider only node locations for facilities, thus making the problem harder to solve. An integer programming formulation is provided. This, like most subsequent formulations, is based on binary decision variables showing whether a station is open at a node and whether a given path has its flow refuelled. However, it also contains a more cumbersome variable that shows whether every facility in a given combination is open. Unfortunately this formulation requires a massive preprocessing effort. All facility combinations must be checked whether they can refuel each origin-destination journey and the resulting coefficients inserted as input into the integer programming model. This takes an immense amount of time, so much so, that the authors could not even generate the integer programming model for their benchmark instance, let alone solve it.

While in a large part of the literature the objective is to maximise the flow captured, the model of Wang and Lin (2009) aims to minimise costs such that all flows are served. The authors devised a "vehicle refuelling logic" that is more involved but also more flexible than that of previous models. Another important difference is that this model requires only knowledge of origin-destination distances, but not of origin-destination flow data.

Lim and Kuby (2010) designed some heuristic algorithms for the FRLM. One of their motivations for doing so is the complexity of the Kuby and Lim (2005) mathematical formulation. There are three heuristics but with a common subroutine to evaluate the objective function value:

- The "greedy-adding" or "add" algorithm simply adds one more facility in each iteration so as to maximise the increase in flow capture.
- The "greedy-adding with substitution" or "add-swap" algorithm also attempts in each iteration to replace an existing facility with a potential facility. Thus, each iteration consists of an "add" and a "swap" move.
- The genetic algorithm is based on the chromosome representation of a list of open facilities. (As the number of facilities is fixed in advance, this is more reasonable than a 0-1 representation.)

Unlike, say, the maximum covering problem, the evaluation of a given solution is not a straightforward task. For a given solution, i.e. a set of facilities, the evaluation subroutine must evaluate every origin-destination path to see whether it is refuelable – if so, its flow is added to the objective function value. We note that all the algorithms are capable of handling pre-existing facilities. The authors found that the greedy algorithms perform quite well, nearly as well as the genetic algorithms, and are significantly faster.

Capar and Kuby (2012) put forward a more complex mathematical formulation, but without the preprocessing requirement of Kuby and Lim (2005). This new formulation is in fact as fast as the greedy heuristics of Lim and Kuby (2010). They replaced the decision variables relating to facility combinations with variables that show whether vehicle on a given path and refuelling (or not refuelling) at a station candidate site have enough fuel remaining to reach the next open fuel station on their path. This is a more efficient formulation in that combination pre-generation is eliminated the number of new decision variables and new constraints significantly increase the size of the model.



Capar et al. (2013) offered a more efficient formulation than Capar and Kuby (2012). While the previous model used a "node-cover/path-cover" logic, the authors propose an "arc-cover/path-cover" model. It is based on the concept that a path can be refuelled if all directed arcs on the round-trip path are served. This eliminates both combination pre-generation and the cumbersome refuelling logic variables of Capar and Kuby (2012).

In the model of MirHassani and Ebrazi (2013), the number of facilities is not fixed in advance, as it explicitly takes into account their establishment costs. This version of the FRLM is known as the fixed-charge FRLM. However, their formulation is adapted also for the case of fixed number of facilities. The logic of their formulation is developed from a single-path to a multi-path formulation. This necessitates the creation of a so-called extended network. The authors provide this formulation but their computation testing was only on the fixed-charge FRLM therefore it is interesting to see how their model compares to the Capar et al. (2013) formulation.

Wen et al. (2014) investigated both maximal flow capture and total flow capture models. Their formulations are based on set covering and do not require the evaluation of all feasible combinations of locations. Ghamami et al. (2016) considered the particular case of locating refuelling stations along a travel corridor, while also allowing for congestion and delay at charging stations. Their formulation is based on the assignment problem. The authors have also designed a simulated annealing metaheuristic.

Finally we note that in this brief review it was not possible for us to describe all variants of the FRLM. Of particular note is the FRLM with deviation. While in the above models it is assumed that in order to capture a flow, a facility must lie on the origin-destination path, it may also be reasonable to assume, especially if the network of facilities is very sparse, that drivers would make some reasonable detours to visit a facility. The reader is referred to Berman et al. (1995), Kim and Kuby (2012), Yildiz et al. (2016) and Lin and Lin (2016). Another interesting problem is the multi-period FRLM, see Miralinaghi et al. (2017).

## **A NEW HEURISTIC FOR THE FRLM**

The idea of using the optimal solution obtained by relaxing the integrality constraints of the mixed-integer linear programming (MILP) problems to generate a set of initial solutions for meta-heuristic algorithms is well-known. Recently, the idea of using the information of the optimal solution to support search process further – namely, to establish a set of promising candidate variables – was developed by Angelelli et al. (2010). This method, known as Kernel Search, identifies subsets of decision variables for the MILP problem by solving the relaxation problem and then solves the restricted problems to optimality by commercial MILP solvers. It has been successfully applied for several optimisation problems, including logistics applications. For example, Guastaroba and Speranza (2012, 2014) solved the multi-source and the single-source capacitated facility location problems, respectively. We develop here an efficient heuristic algorithm, based on the concept of restricted subproblems, for solving the alternative-fuel station location problem. Compared with Kernel Search algorithm, our algorithm has some small differences as follows:

- Although there are two sets of binary variables in the problem, we only explicitly restrict on the location variables. The number of path variables is determined based on the restricted location variables. Thus, there is implicit restriction. Restricting on one set of binary variable may help the proposed algorithm obtain the good balance of solution quality and CPU time, instead of restricting on all the sets of binary variables as in Kernel Search algorithm.
- The size of the restricted subproblems equals to the number of location variables with positive value. In Kernel Search algorithm, size of the restricted subproblems is usually a given arbitrary parameter. As a result, initial promising variable set may include

variables with zero relaxed value or remove variables with positive relaxed value. This may lead to spend additional CPU time to find the best solutions.

- A 2-exchange neighbourhood is used to generate a pool of the restricted subproblems for parallel computing strategy.

We use the formulation of Capar et al. (2013) as the basis. Solving the relaxation of this yields us the set of promising nodes – those with non-negative relaxed values. To further reduce the size of the subproblems to be solved, we remove paths that cannot be refuelled by a set of restricted nodes. Then, we generate a set of restricted subproblems by performing 2-exchange on the set of promising nodes. These can be grouped and each group allocated to a CPU core to enable parallel processing.

In more detail, the algorithm can be described as follows:

1. Solve the original problem relaxed on the constraints of binary variables. If solution is integer, stop.
2. Set upper bound and classify vertices into promising nodes  $N^*$  (those with positive value) and other nodes  $N^0$  (those with zero value).
3. Determine restricted set of paths based on  $N^*$ . Solve restricted subproblem and update bounds. If bounds sufficiently close to each other, stop.
4. Create several sets of restricted nodes by exchanging 2 nodes between  $N^*$  and  $N^0$ . Allocate these to parallel CPU cores and solve restricted subproblems simultaneously. Update upper and lower bounds.
5. If bounds are close to each other *or* all restricted problems have been solved *or* a given number of restricted problems have been solved, stop; else return to Step 4.

## COMPUTATIONAL EXPERIENCE

In this section, we investigate the computational efficacy of solving the FRLM with the heuristic algorithm proposed. We evaluate the performance of the heuristic algorithm on two well-known benchmark datasets and then compare the obtained results with the optimal solutions from CPLEX solver as well as other heuristic algorithms. The models and the proposed algorithm were implemented in Visual C++; the models were built and solved using the IBM ILOG CPLEX version 12.4.

The computational experiments were run on two well-known benchmark datasets:

- Hodgson dataset (Hodgson, 1990): This is a 25-node alternative-fuel station location network. The flow volumes in the  $25 \times 25$  origin-destination matrix are estimated using a gravity model. The flows are then assigned to their shortest paths. The candidate sites are limited to the 25 nodes of the network. The network has 300 origin-destination pairs.
- Florida dataset (Kuby et al., 2009): This is a Florida state highway network consisting of 302 nodes (i.e. junctions) and 495 arcs. Each of the nodes serves as a candidate site. Of the 302 candidate sites, there are 74 origin-destination nodes for trips. Since the return trip is assumed to be refuelable, the network of 74 origin-destination nodes only requires 2701 unique origin-destination pairs.

For the evaluation of computational experiments, a set of scenarios are generated by changing the range of vehicles  $R$  and the number of stations to be located  $p$ .  $R = 4, 8$ , and 12 are used for Hodgson network and  $R = 100$  is used for Florida network. Both are tested with  $p = 5, 10, 15, 20$  and 25.

The instances were solved using the formulations of Capar and Kuby (2012) [CK], Capar et al. (2013) [CKLT], MirHassani and Ebrazi (2013) [ME], the genetic and greedy algorithms of Lim and Kuby (2010) [LKGenA and LKGreA] and our heuristic [HA]. Results are presented in Tables 1 and 2. Note  $\Delta$  stands for percentage deviation from optimum and time is given in seconds. Lim and Kuby (2010) did not give computing times for the Hodgson dataset.

Table 1: Comparison for the formulations and the algorithms on Hodgson instances.

R	p	CK		CKLT		ME		LKGenA		LKGreA		HA	
		$\Delta$	time	$\Delta$	time	$\Delta$	time	$\Delta$	time	$\Delta$	time	$\Delta$	time
4	5	0	0.24	0	0.12	0	0.13	0	-	0	-	0	0.12
	10	0	0.20	0	0.14	0	0.12	0	-	10.75	-	0	0.13
	15	0	0.18	0	0.08	0	0.10	0	-	0	-	0	0.05
	20	0	0.18	0	0.08	0	0.10	0	-	0	-	0	0.05
	25	0	0.16	0	0.10	0	0.10	0	-	0	-	0	0.05
8	5	0	0.28	0	0.14	0	0.14	0	-	0.49	-	0	0.15
	10	0	0.32	0	0.18	0	0.18	0	-	0.93	-	0	0.26
	15	0	0.28	0	0.14	0	0.15	0	-	0	-	0	0.27
	20	0	0.20	0	0.12	0	0.11	0	-	0.15	-	0	0.05
	25	0	0.18	0	0.10	0	0.10	0	-	0	-	0	0.06
12	5	0	0.84	0	0.16	0	0.44	0	-	0	-	0	0.21
	10	0	0.30	0	0.16	0	0.16	0	-	0	-	0	0.07
	15	0	0.24	0	0.14	0	0.13	0	-	0	-	0	0.07
	20	0	0.28	0	0.14	0	0.14	0	-	0	-	0	0.07
	25	0	0.20	0	0.12	0	0.11	0	-	0	-	0	0.07
Average		0	0.27	0	0.13	0	0.15	0	-	0.82	-	0	0.11

Table 2: Comparison for the formulations and the algorithms on Florida instances.

R	p	CK		CKLT		ME		LKGenA		LKGreA		HA	
		$\Delta$	time	$\Delta$	time	$\Delta$	time	$\Delta$	time	$\Delta$	time	$\Delta$	time
100	5	0	148	0	34	0	76	0.71	182	0	33	0	28
	10	0	210	0	29	0	101	0.41	1352	0.43	174	0	29
	15	0	341	0	32	0	165	0.16	2412	0.50	456	0	30
	20	0	492	0	75	0	251	0.10	5800	0.31	1132	0	74
	25	0	999	0	138	0	512	0.10	10646	0.38	1800	0	129
Average		0	438	0	62	0	221	0.30	4078	0.32	719	0	58

Both tables confirm the efficiency of our heuristic algorithm. It finds the optimal solution for all the instances tested above, with computing times on most instances slightly below those of Capar et al. (2013). Our algorithm significantly outperforms both heuristics of Lim and Kuby (2010) in terms of solution quality and CPU time. For example, we only need 129 seconds to find the optimal solution for the Florida instance ( $R=100$ ,  $p=25$ ), while LKGenA and LKGreA take about 3 hours and about half an hour respectively, yet do not find the optimal solution. As an additional observation, we can see that the MirHassani and Ebrazi (2013) formulation is slightly less efficient than the Capar et al. (2013) formulation – these have not previously been compared to each other.

## CONCLUSIONS AND SUGGESTIONS

The design of a heuristic algorithm for the alternative-fuel station location problem is an important issue that has not received appropriate attention in the research. In the paper, we thus develop an efficient heuristic algorithm to locate optimal refuelling stations for the maximisation of round-trip traffic volume. The algorithm is constructed on solving the sequence of restricted problems by a set of promising station candidates, and by a number of the best promising stations to be located. To determine the initial set of candidates we solve a relaxation model of the original problem with the constraints of integer variables relaxed, and then update the set in next iterations by performing 2-exchange between the set of promising candidates and the remaining station set. As solving the restricted problems, we locate the best stations in the set of promising candidates to improve the computation time of the algorithm. Besides that, we use a parallel computing strategy to simultaneously solve a number of restricted problems with less computation effort for large-sized instances. Experimental results show that the proposed algorithm can obtain the optimal solutions with less computation time

(compared with CPLEX solver), and outperforms the other compared algorithms (i.e., genetic algorithm and greedy algorithm) with respect to solution quality as well as computation time.

From the successful results obtained, we can extend the heuristic algorithm to handle other interesting alternative-fuel station location problems, such as:

- The FRLM with deviation (Kim and Kuby, 2012, Lin and Lin, 2016),
- The fixed-charge FRLM (MirHassani and Ebrazi, 2013),
- The multi-period FRLM (Miralinaghi et al., 2017).

It would be very interesting to apply our algorithm to practical applications, which we believe may arise in the near future, especially in the light of the recent EU directive on the establishment of a Europe-wide alternative fuel infrastructure (European Commission, 2014). In this respect, the reader is referred to the recent application study by Kuby et al. (2017), focusing on natural gas refuelling stations in the E.U. Another possible application would be for the location of alternative fuel stations for the railways. While the algorithms presented in the literature could be just as applicable to rail transport as to automobiles, most papers tackle the FRLM in the context of automobile refuelling stations. Yet, as Kuby and Lim (2005) has already pointed out, there is much better origin-destination flow data available for railways, making this mode of transport an ideal field of applying FRLM models.

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# PHARMACEUTICAL SUPPLY CHAIN (PSC) FOR EFFECTIVE HEALTHCARE DELIVERY: A CASE STUDY OF COMPK LTD

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## ABSTRACT

**Purpose of this paper:** The pharmaceutical industry develops, produces, distributes and markets medicines. The industry is highly regulated with strict restrictions on patenting, testing, marketing, safety of manufactured and supplied medicines. Medicines are an integral part of the Pharmaceutical Supply Chain (PSC), involving many markets, products, processes and intermediaries. Contentious issues include the availability, accessibility, affordability and quality delivery of efficacious medicines, to the right places and consumers at the right time. Complexities of the interactions between players such as government bodies, healthcare purchasing and distribution groups, healthcare providers and manufacturing companies, have resulted in attention towards the value-chain transformation concept to fix any healthcare systems. The purpose of this study is to 1) Examine the supply chain practices of Compk Ltd within the PSC. 2) Analyse challenges and constraints on Compk Ltd's distribution of pharmaceutical and healthcare products in Nigeria and 3) Propose a conceptual framework for Compk Ltd to overcome the challenges for effective and efficient distribution of healthcare products in Nigeria.

**Design/methodology/approach:** An exploratory qualitative research design using semi-structured interviews was employed in the case study of Compk Ltd. The researcher used Nvivo 11 software to manage, explore, and find patterns from transcribed semi-structured interview responses and employed qualitative thematic analysis for evaluating, interpreting and explaining Compk Ltd's practices that contribute to value creation in healthcare delivery in key areas linked to their PSC.

**Findings:** The study revealed social, economic and environmental factors such as pricing, regulatory change, actions by distributors impacting Compk Ltd and consumers of healthcare products in Nigeria. Key findings include; Consumers are cautious, spend a lot of their disposable income on medicines, make connection between prices and quality in purchasing medicines and are inclined to purchase heritage brands.

**Value:** This study researches for the first time Compk Ltd's practices, business drivers, challenges and constraints and the potential value that could be added to medicine manufacturers upstream and consumers downstream in the PSC as Pharmaceutical companies are expected to extensively pay attention to their customers to improve their supply chain activities (Ghatari et al., 2013).

**Research limitations/implications (if applicable):** This paper is based on a single case study, Compk Ltd, therefore it limits generalising the findings.

**Practical Implications (if applicable):** Further research design using questionnaire on the target population will be adopted to understand consumer's motives for buying medicines, to understand consumer behaviour impacting their decisions.

**Keywords:** Pharmaceutical, Supply Chain, Healthcare, Innovation

## **1.0 INTRODUCTION**

Healthcare and pharmaceuticals comprises an ever-increasing percentage of the GDPs of most countries and is projected to grow further in importance with the ageing of the world population, although growing older is cause for celebration, with unprecedented gains in life expectancy, the result of continued economic development and advances in healthcare and technology. However, population ageing will also pose an economic and fiscal challenge (Mukherjee, 2007; World Economic Forum, 2015).

There are acute disparities in pharmaceutical access between developed and developing countries (Cohen, 2005). Healthcare issues are global, even if care is usually delivered locally, while the effects of these issues are influenced by local factors, many challenges such as lack of access, rising costs, increasing competition, competition across therapeutic segments, increasing healthcare customization, changing healthcare policies and industry dynamics, counterfeiting, introduction of alternative treatments and uneven quality, etc. are shared around the world to varying degrees, as are the opportunities to innovate to solve these issues (Deloitte, 2014; Narayana, 2014). Therefore, opportunities to fix any healthcare system will involve a value transformation agenda.

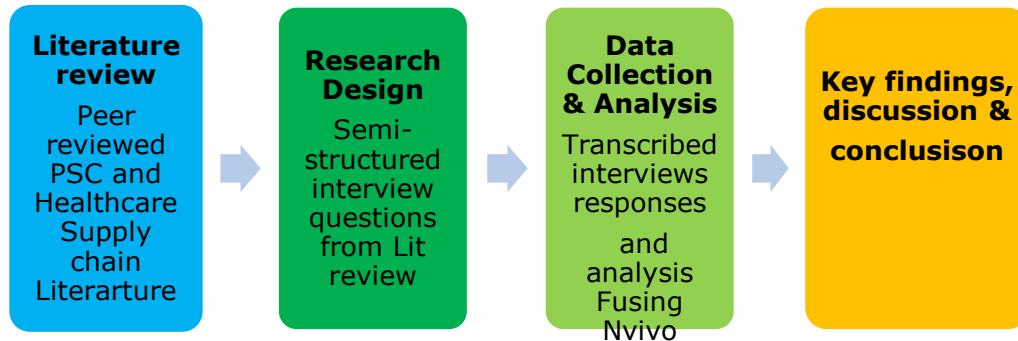
## **2.0 LITERATURE REVIEW**

The researcher conducted a systematic review of PSC literature in peer-reviewed academic journals as outlined by Tranfield et al., (2003), Pittaway et al., (2004) and Macpherson and Holt (2007) and used keyword search in electronic databases such as Elsevier, Emerald, Web of Knowledge, Science Direct and Google scholar. In order to find articles related to pharmaceutical supply chain and healthcare delivery, followed by content analysis of cited references. Literature depicts an increasing but fragmented interest in supply chains in health services (de Vries and Huijsman, 2011) others explored specific countries such as healthcare reforms (Yu et al., 2010), sourcing decisions (Pazirandeh, 2011), called for integrating research efforts from R&D to final healthcare amore studies in developing countries for significant opportunities and for better value creation approaches in healthcare delivery in key areas linked to Pharmaceutical Supply Chain (PSC) management (Schneller and Smeltzer, 2006; Narayana et al., 2012; 2014). Existing PSC research focuses on developed economies with gaps in the countries of Africa between basic universal health care and what is provided (Kumar et al., 2009). Emerging markets represent the fastest-growing segment of the global pharmaceutical industry with approximately half of the population in Africa lacking regular access to essential medicines, and approximately 90 per cent of medicines are imported (WHO, 2005; Chaudhuri et al., 2010). There is a lack of systematic information collection regarding demand and supply in the pharmaceutical supply chain of developing countries. Currently, the health sector is characterized by lack of effective stewardship role of government, fragmented health service delivery, inadequate and inefficient financing, weak health infrastructure, mal-distribution of health work force and poor coordination amongst key players (Osotimehin, 2009). The health indicators in Nigeria have remained below country targets and internationally-set benchmarks including the Sustainable Development Goals (SDGs) and previously the Millennium Development Goals (MDGs) which have recorded very slow progress over the years. Apart from health services, supply chains of healthcare products are important contributors to the healthcare system. Different healthcare products are distributed and traded differently and vary in their cost, criticality to delivery of patient care and potential impact on service improvement (Zheng, et al., 2006). Narayana (2014) calls for an integrated research effort on value delivery and more studies in developing countries.

## **3.0 RESEARCH METHODOLOGY**

An interview protocol was developed from the review of relevant PSC and healthcare supply chain literature in order to answer the research questions. A company case study was employed (Yin, 2013). Data was collected from semi-structured interviews held with key

employees in an in-depth case study of Compk Ltd, review of company documents, and observations were conducted to ensure data triangulation. Due to confidentiality, the name of the company has been anonymised in this paper. Case study research has recently been used in PSC research, this approach provides flexibility the data collection and triangulation are applied to increase the research quality (Saunders et al., 2009; Locke et al., 2000). The research process employed in this study is illustrated in Figure 1 below.



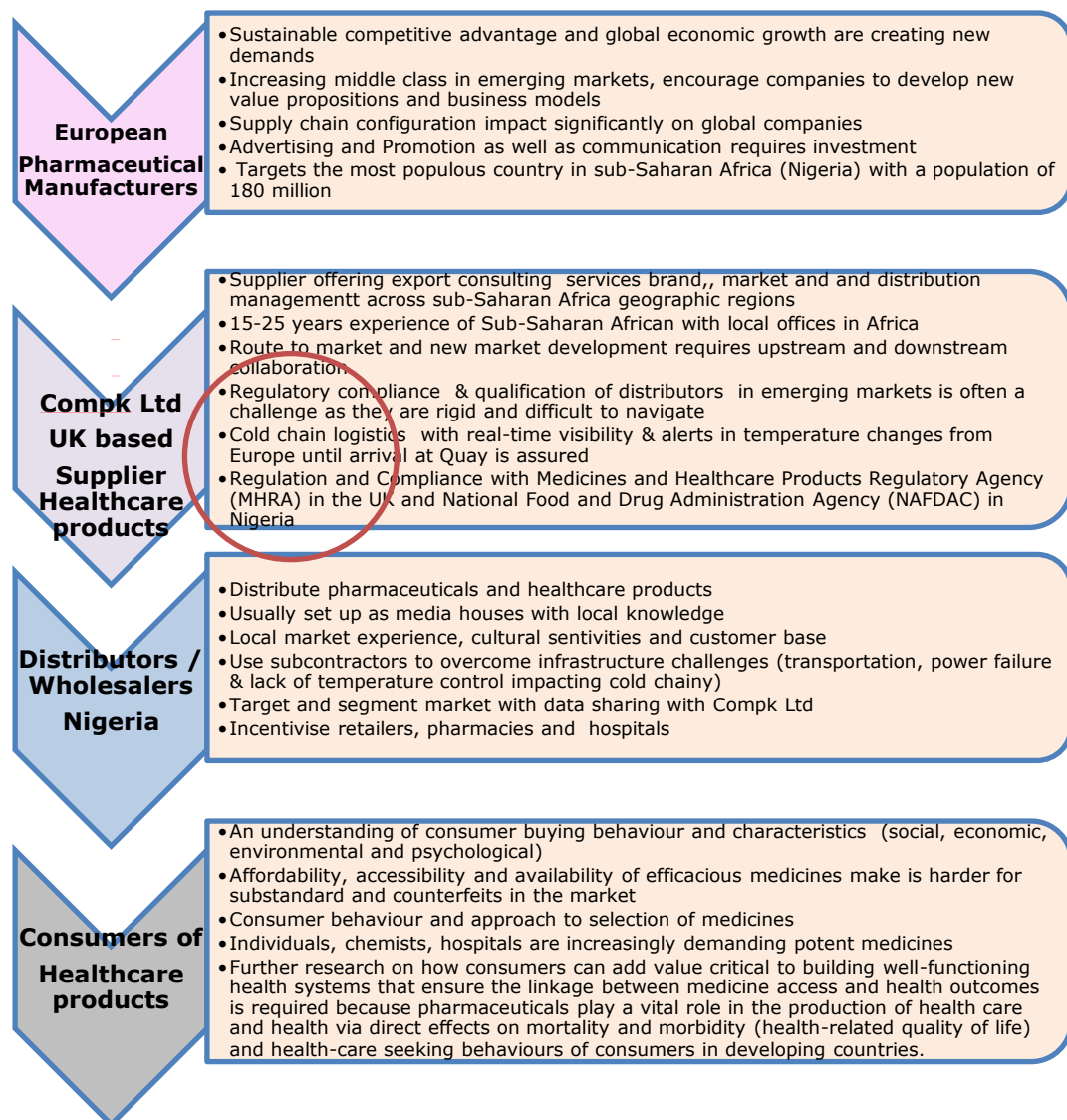
**Figure 1: Research Process**

In healthcare studies, real-time data are needed to deliver better and faster decisions. Qualitative exploratory research of a single case study Compk Ltd helped to gain an in-depth understanding of PSC practices, challenges and constraints in developing countries as well as discover new ideas for further studies in the field, in Nigeria. Data gathered and transcribed from semi-structured interviews was analysed by inductive open coding, using the qualitative software Nvivo version 11, and the software assisted in clustering text after the coding and sorting process. This was followed by an in-depth thematic analysis of the dominant and emerging topics discussed in this papers. One of the main functions in Nvivo is the query result of frequently used word gathered from literature review documents and transcribed interview responses imported into Nvivo for coding and processing as shown in Figure 2.





Compk Ltd have 15 to 25 years knowledge of exporting pharmaceutical and healthcare products to developing countries and act as a service provider to international brands. European pharmaceuticals and healthcare product manufacturers engage Compk Ltd to take ownership of manufacturer's non-registered products (e.g. over the counter medicines, sanitisers, feminine & hygiene products). Compk Ltd take the products through registration and oversee other activities including compliance, cold-chain, and storage, transportation, air freighting or shipping to sub-Saharan geographic and regional markets. Compk Ltd provide consulting services, demand-driven market and partner with local media agencies for distribution management. The route to market involves Compk Ltd liaising with existing wholesalers or distributors in these markets or the identification, vetting and selection of new wholesalers and distributors based on their knowledge of the market. Prospects are qualified based on their experience of the target market, customer base, market coverage and infrastructure (storage, transport and logistics). Figure 3 below shows CompK Ltd's position in the supply chain and the drivers for engagement and collaboration activities from European Pharmaceutical manufactures. Compk Ltd, Suppliers of Pharmaceutical and Healthcare Product Manufacturers.



**Figure 3.** A Conceptual Framework for effective and efficient distribution of healthcare products.

### 4.3 PSC Challenges and Enablers

Pharmaceutical manufacturers entering a foreign market face a plethora of challenges in the entire health supply chain ranging from manufacturing, storage, distributions, infrastructures (power, water and transportation), and catastrophic administrative failures of health establishments. These translates into consumers of pharmaceutical products experiencing difficulties in obtaining regular access to safe, efficacious, good quality, affordable medicines and the risk of exposure to counterfeit drugs all of which negatively impact the wellness of consumers. Key findings identified from Compk Ltds employee interview responses are as follows;

**Regulation:** Compk Ltd have regular contact with different regulatory bodies. These organisations provide regulatory guidelines for pharmaceutical, food and other healthcare products manufactured in Europe and exported to Africa. Medicines and Healthcare Products Regulations Agency (MHRA), regulates medicines, medical devices and blood components for transfusion in the UK. Recognised globally as an authority in its field, the agency plays a leading role in protecting and improving public health and supports innovation through scientific research and development. They regulate Compk Ltd's activities in their export of pharmaceutical and healthcare products. An interviewee stated that "We had some recent changes in here, not changes, and we doing things all rights as by confirmed by the MHRA during their last inspection visit". In Nigeria, the increasingly visible and active medicines regulatory authority, the National Agency for Drug Administration and Control (NAFDAC) has increased consumer confidence by ensuring medicines are registered and NAFDAC registration numbers are displayed on the packaging.

**Infrastructure:** Poor infrastructure (power, water and transportation) increases the cost of medicine manufacture and distribution whilst hampering growth. This could have severe consequences on the delivery of substandard medicines such as when temperature control cannot be guaranteed along the supply chain before the medicines get to the final consumer. There are risks with medicines requiring temperature control and require monitoring, achieved by placing loggers in the packaging and carrying out multiple inspections when the medicines leave the port of entry in Nigeria.

**Distributor:** Distribution networks in African countries have evolved into numerous small private wholesalers, who are "middle-men," and few medium- to large-scale wholesalers (Tetteh, 2009). In Compk Ltd's experience, uncontrolled and chaotic medicine distribution system and parallel imports from competitors undercutting the market often compromise the safety and standards of medicines getting to the final consumer.

**Supply Chain:** Pharmacists have immense product knowledge but limited knowledge of the pharmaceutical supply chain and consumer needs. Chemists could employ educated staff or provide training on reporting systems on inventory and stocks.

**Pricing:** Consumer show a preference for branded and imported products. Consumers pay for medicines out of pocket and are willing to pay the premium for branded medicines. High price is associated with high quality

**Access:** Access to essential medicines is very limited in rural poor communities due to high cost and restricted access to medicines.

Compk Ltd select and engage distributors with wide coverage who distribute to retailers, pharmacists, chemist, medicine store and hospitals. Products purchased at chemists or hospitals are relatively safe. Customers are at risk of unknowingly purchasing counterfeit medicines at cut rate prices through the open market.

**Technology:** New technology is changing the way data are collected and disseminated with 95 per cent of the global population covered by a cellular network. New data collection technologies, such as Computer-Assisted Personal Interviewing (CAPI) and mobile text surveys (SMS), and new data sources, such as social media posts, online search records and mobile phone call records, allow faster data collection and provide near real-time information. Consumers of medicines are therefore more informed and can make choices and check that medicines are safe.

**Advertising and Promotion:** Compk Ltd recognised the importance of developing brands to attract consumers of pharmaceutical products experiencing challenges in obtaining regular access to safe, efficacious, good quality, premium medicines. Brand owners come up with the message on who they are targeting and how they communicate with families, hospitals, pharmacists. Media houses are used for promotion and organising media locally, suggesting what should be done and how it should be done. Consumers are cautious, spend a lot of their disposable income on medicines, make connection between prices and quality in purchasing medicines and are inclined to purchase heritage brands as some of the factors built into a conceptual framework proposed for further investigation of consumer decision process in interaction for value addition to the Pharmaceutical Supply Chain in Nigeria.

## 5.0 LIMITATION

Social, economic and environmental factors such as pricing, regulation and actions by competitors, are factors that affect Compk Ltd in the developing countries markets and there are differences in PSC configuration across regions, according to various circumstances e.g. different cultures, economy, rules, regulations, traditions and legal systems. The pilot study was based on once company and there are limits to generalising for similar companies in the industry.

## 6.0 CONCLUSION

Pharmaceuticals play a vital role in the production of health care and health via direct effects on mortality and morbidity (health-related quality of life), and indirect effects on productivity of health-care staff and health-care seeking behaviours of consumers, reduced medicines' access reinforces the vicious poverty-ill health cycle. The task of ensuring population's access to quality essential medicines at affordable prices is among the prime challenges facing many governments in the management of public health systems in developing countries. The creation of an integrated pharmaceutical supply chain depends on all parties involved; manufacturers, distributors, consumers, healthcare professionals and researchers. Further, investments in Pharmaceutical Supply Chains particularly on how consumers can add value is critical to building well-functioning health systems that ensure the linkage between medicine access and health outcomes is sustained over time. This will be the next stage of the research.

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## **Session 3: Customer-Supplier Relationships**

# THE ENABLERS TO ACHIEVE SUPPLY CHAIN AGILITY IN FMCG INDUSTRY: EMPIRICAL EVIDENCE FROM GERMANY

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## ABSTRACT

### Purpose of this paper:

Supply chain (SC) agility enables companies to react quickly and more effectively to marketplace volatility and other uncertainties, thereby allowing them to establish a superior competitive position (Lee, 2004). In particular, SC agility is an essential characteristic for SCs to survive in dynamic markets such as innovative product manufacturing industry and fast moving consumer goods (FMCG) industry. Many previous studies have sought the enablers, characteristics, and index of SC agility including how to achieve it with various manufacturing contexts (i.e., Swafford et al. 2006). Nevertheless, surprisingly major barriers of achieving SC agility have yet to be rigorously disclosed in the prior studies, and it appears that they have neglected how to achieve SC agility in FMCG. The core research question will be "How can FMCG industry achieve SC agility?"

### Design/methodology/approach:

Although Agarwal et al. (2007) has undertaken interpretive structural modelling (ISM) to analyse agile SC with automotive industry in India, this study expanded their model with a focus on German FMCG industry. Firstly, it conducted a series of interviews with practitioners to achieve SC agility in the FMCG industry. Secondly, it analysed 12 enablers found in the interviews using ISM in order to graphically demonstrate the interrelationships of those enablers. Lastly, the result was discussed based on the interviews and extant studies.

### Findings:

The analysis showed that SC agility stems from the interactions of collaborative practices within a SC (i.e., process integration, communication channels, trust and supply chain collaboration), which leads to the diffusion of market information. These enablers generate unique corporate cultures, such as change alertness and sensitivity to the market. The cultures affect the competencies of flexibility and lead time reduction, which will eventually create an agile SC.

### Value:

This study empirically found a common fundamental understanding of SC agility. It examined enablers that are relevant for achieving SC agility in German FMCG industry, and found that these enablers are highly interrelated to each other. The FMCG industry can achieve SC agility by fostering collaborative practices, market-sensitive corporate cultures and core competencies.

### Research limitations/implications (if applicable):

First, the elements were selected through group discussions of selected participants, so the selection may have some biases. Second, this study solely focuses on the FMCG industry, thus, its finding is limited to this sector. The same applied to the country

(Germany). Third, the cross-sectional research design illustrates a snapshot and thereby limits the horizon of the research. The future research may conduct a longitudinal study.

## **INTRODUCTION**

The best supply chain (SC) is not just fast and cost-effective, but it should be also agile because high-speed and low-cost SCs sometimes fail to react to unexpected variations in supply and demand and to adapt to changes in the market structure (Lee, 2004). SC agility enables companies to react quickly and more effectively to marketplace volatility and other uncertainties, thereby allowing them to establish a superior competitive position (Swafford et al., 2006). Moreover, companies with agile SCs achieve improved market sensitivity as well as better alignment of supply and demand. As SC agility has an impact on the company's ability to yield innovative products and the delivery to their customers, the concept of SC agility may result in an overall competitiveness at the strategic level. Li et al. (2008) noted that business structure and processes, SC agility and organisational performance are inevitably interrelated in many ways. Also, SC agility helps to manage SC disruption risks and ensure uninterrupted service to customers, because the firms can respond swiftly to predicted and actual disruptions in the SC (Braunscheidel and Suresh, 2009; Blome et al., 2013).

In particular, SC agility is an essential characteristic for SCs to survive in dynamic markets such as innovative product manufacturing industry and fast-moving consumer goods (FMCG) industry (Gligor and Holcomb, 2012b). The FMCG industry is dominantly shaped by large multinational companies which provide a broad range of products and brand portfolios. The examples of worldwide leading companies are Nestlé, Procter & Gamble, PepsiCo, Unilever, and Coca-Cola. Due to various challenges such as shorter product life cycles, demanding customer requirements, longer lead times, and heightened supply and demand volatility, market visibility has significantly shortened and thereby increased uncertainty (Swafford et al., 2006). Therefore, effectively managing FMCG SC is not an easy task (Gligor, 2014). In FMCG context, SC agility has developed as the prevailing competitive concept for companies working in unpredictable and constantly changing-business environments (Gligor et al., 2013).

Germany has some major FMCG giants. The largest manufacturers of FMCG in Germany are Henkel, Dr Oetker and Beiersdorf. In general, this industry is characterised by low margins which lead to consolidation of high volumes. The German FMCG industry accounted a growth of 2.5% in 2013 and shows a steady growth (GfK, 2015). With regards to the Food-Segment, German consumers spend more than 200 billion Euros for food, beverages and tobacco each year. This corresponds to a share of less than 14% of the whole private consumer spending. The so-called Nearfood-Segment generates a turnover of 17 billion Euros in Germany from which personal care products and cosmetics account for about 13 billion Euros and detergent and cleaning agents amount 4 billion Euros.

The major distribution structures for FMCG are food retailers and drugstores. In Germany, the most important shopping locations for FMCG are discounters and consumer markets. According to an estimate of the GfK (2015), more than 40% of the food retailing turnover is generated by discounters. The food retailing business is characterised by a high concentration as the five leading groups have a market share of more than 80% in Germany (GfK, 2015). Despite the growth of the FMCG market, companies in this industry still have to face numerous challenges. In particular, SCM in this industry becomes more and more complex. The main complexity drivers in FMCG SCs are derived from a high variety of products and stock keeping units (SKUs), variation in demand, variation in capacity requirements, a complex network with a high number of suppliers and distribution points (Serdarasan, 2013). It should be noted that German FMCG industry is tough because the discounters are price-sensitive due to years of 'Aldi-tification', and take advantage of their strong market position and exercise huge pressure on the purchase prices. As a consequence, FMCG manufacturers seek to agile SC by reducing complexity in their SCs so as to achieve cost efficiencies and thereby to cope with this cost pressure.



Many previous studies have sought the enablers, characteristics, and index of SC agility including how to achieve it with various manufacturing in numerous countries. This study expands Agarwal et al. (2007)'s model, which undertook interpretive structural modelling to analyse agile SC in the Indian automotive industry, with a focus on German FMCG industry. Hence, the characteristics of SC agility in a FMCG industry can contribute to shedding a light to current SC agility knowledge. As such, this study can contribute to theory development as well as improve managerial knowledge and practices (Swafford et al., 2006). In addition, the theories pertaining to SC agility is divided into various fragments (Li et al., 2008). This multidimensionality has resulted in much confusion and a lack of clarity (Gligor and Holcomb, 2012a). The linkages between the factors of SC agility in FMCG industry are not sufficiently investigated, so the interrelationship of SC agility factors has room to further investigate (Li et al., 2009). Since the FMCG industry has a complex SC design and faces numerous challenges, the finding of this study may be beneficial to the SC managers in the given industry by providing room to ponder as they strive for fresh insights into what it takes to realise more agile SCs for FMCG industry. To this point, exploring the interrelationships of factors that determine the level of SC agility in FMCG industry as well as the barriers to achieving it may broaden the knowledge of SC agility.

Recognising the upward importance of obtaining SC agility, this study thus has following research questions: "what are the barriers to SC agility in FMCG industry?", "How does FMCG industry achieve SC agility?", and more specifically "what are the interrelationships of the contributing factors to SC agility?" in case of German FMCG industries.

## **AGILITY**

SC agility is viewed as a leading competitive vehicle. Many researchers have contended agility as a trait closely linked to the effectiveness of strategic SCM (Li et al., 2008; Lee, 2004). It can facilitate resource configuration and can enable sensing environmental changes (Li et al., 2009). It is also conceptualised as higher order dynamic capabilities that have an impact on cost and operational performance (Eckstein et al., 2015). SC agility allows firms to better synchronise demand and supply, lowering inventory and transport costs. As one way of SC agility strategy, postpone can lead to lower cost of inventory, transportation and production via minimum stocking (Christopher, 2000). Furthermore, any disruptions resulting in production stops can be avoided by agile SC, which helps to optimise SC cost (Blome et al., 2013). Lee (2004) noted that most SCs survive by managing speed against costs, but agile SC responds both quickly and cost-effectively, and agile SC can benefit from shortened times of materials and services and rapid adjustment of production processes to customise products cost-effectively. Greater responsiveness to changes in product mix and volume via automation helps them to yield better delivery and quality performance (Gligor and Holcomb, 2012a). In addition, an ability of SC agility to recuperate from unanticipated shocks yields higher delivery performance (Lee, 2004).

Up to now, several definitions of the term SC agility have been proposed, although there is no commonly agreed definition. This may lie in the continuous development of the concept and extended scope over time. Nonetheless, current definitions are similar with regards to their terms and themes they include, implying that a certain level of agreement exists (Gligor and Holcomb, 2012b). Most studies have put an emphasis on rapidly changing operating states within the supply chain's structural configuration (Eckstein et al., 2015). Li et al. (2008, p. 421) propose the following unifying general-purpose definition: "Agility is the result of integrating an alertness to changes (opportunities/challenges)-both internal and environmental-with a capability to use resources in responding to such changes, all in a timely, and flexible manners". It appears that this definition is comprehensive and contains aspects that need to be considered to achieve SC agility. Therefore, this research adopts Li et al. (2008)'s definition throughout the paper.

## **ENABLERS OF SC AGILITY**

A considerable body of literature has examined the SC agility enablers (Gligor and Holcomb, 2012b). Amongst many important enablers, the key enabler of SC agility is change (Lin et al., 2006). Agile SCs are required when demand is unstable and the requirement for variety is high (Christopher, 2000). In order to achieve agile SCs, companies need to consider and understand relevant factors which are necessary for this capability. In his early study, Christopher (2000) identified some distinguishing enablers for a SC to be truly agile: the quality of supplier relationships; a high level of shared information; and a high level of connectivity between firms in the SC. In a similar vein, Van Hoek et al. (2001) claimed that having knowledge and information pertaining to the marketplace is imperative. Notably, Agarwal et al. (2007) found the interrelationships of 15 variables that indicate agile SC such as market sensitiveness; delivery speed; data accuracy; new product introduction; centralised and collaborative planning; process integration; use of IT tools; lead time reduction; service level improvement; cost minimisation; customer satisfaction; quality improvement; minimising uncertainty; trust development; and minimising resistance to change. Lin et al. (2006) suggested four types of enablers to be truly agile SC: cooperative relationship; process integration; information integration; and marketing/customer sensitivity.

In order to identify the enablers of agile SC in this study, we have conducted rigorous literature review and discussions with practitioners in German FMCG industry. After a series of discussions, 10 enablers of agile SCs that fit with the German FMCG industry were identified.

#### (1) Market Sensitivity

Naylor et al. (1999) noted that agility implies the usage of market knowledge. Agile SC is needed to be market sensitive and hence nimble (Christopher and Towill, 2000). Market sensitivity implies that the SC is capable of reading and responding to real demand via transmitting point-of-sale data (Christopher, 2000). A large number of companies still operate on the basis of a forecast rather than demand (Christopher, 2000), implying that they should forecast with basis on the previous sales for preparing adequate level of inventory due to little direct feed-forward from the marketplace (Christopher and Towill, 2000). However, the development of Efficient Consumer Response (ECR) and Information Technology (IT) enables companies to capture data directly from the point-of-sales. Thus, they are better able to read the demand of the market and accordingly respond quicker (Christopher, 2000). Also, they are capable of mastering sudden change and uncertainty (Lin et al., 2006).

#### (2) Market Information Sharing

The sharing and diffusion of market information across the SCs can facilitate the manufacturer's capability to prepare the sudden changes of the demand. In particular, this aspect has paramount importance in FMCG sector due to short market visibility. Once a market change is noticed via the alertness, organisations should be able to receive related data to decide how to offer an agile response. Sharing data between suppliers and buyers can help them to generate a virtual SC, which is information-based, rather than inventory-based (Christopher and Towill, 2000).

#### (3) Process Integration

Process integration is a ground for SC, implying that SC is a confederation of partners linked into a network (Lin et al., 2006). Non-integrated processes and non-integrated distribution process with suppliers and customers may lead to the recipes of the company's failure (Agarwal et al., 2007). In order to fully facilitate information sharing across the SC, process integration between SC partners is required. Process integration includes collaborative working, joint product development as well as the use of the common systems and shared information (Christopher, 2000; Christopher et al., 2004). Such process integration can provide firms with a room for focusing on the core competencies and outsourcing all other activities (Christopher and Towill, 2000).

#### (4) SC Collaboration

In order to acquire a level of SC agility, organisations need to collaborate and align with suppliers and customers to coordinate operations (Lin et al., 2006). Such collaboration and alignment would be a fundamental principle for building SC agility (Gligor and Holcomb, 2012b). Collaborative relationships with SC partners enable to respond quickly and to share relevant information actively, since organisations with a high level of collaboration may possess higher visibility and operational knowledge. Furthermore, firms work together to design and re-engineer components, processes and products and formulate contingency plans (Lee, 2004). Some extant studies empirically identified SC collaboration as a core determinant of SC agility to ensure connected and coordinated response to meet unanticipated changes (Braunscheidel and Suresh, 2009).

#### (5) Willingness to SC Agility

Willingness to SC agility includes a well-recognised need for SC agility (Sangari et al., 2015). SC agility should be incorporated from a strategic to an operational level. Sangari et al. (2015) noted that embracing agility into the strategic vision, objectives of SC, SC operation strategy, SC strategic decisions and each SC partner of the network's strategy is imperative in building agile SC. They also highlighted that a strong belief in the value of SC agility, providing adequate technical and financial support, commitment and involvement in reengineering the SC and logistics, and creating agile supporting culture are highly required. Besides, management has to try to minimise resistance, since resistance to change has been considered as a crucial factor that affects organisations' success and their effort to changes (Argarwal et al., 2007).

#### (6) Trust

SC activities need to encompass major cultural changes such as the establishment of trust between buyers and sellers in the SC (Braunscheidel and Suresh, 2009). The ethos of trust is a foundation in developing SC agility and successful SCM (Christopher and Towill, 2000) because effective information sharing entirely relies on trust within the firm and ultimately extending to SC partners. Also, it is attributed to a fact that building agile SC inevitably need to involve a higher level of interdependency between SC partners. If there is a high degree of trust between SC partners, it is likely to speed up actions within SC and thereby improve the responsiveness. Trust can determine the willingness for unprotected interactions and thus act as the main requirement to increase responsiveness. In general, trust exists when one party has confidence in an exchange partner's reliability and integrity.

#### (7) Flexibility

Flexibility has been regarded as a key characteristic of agility (Christopher and Towill, 2000). Agility is a broader concept that embraces flexibility (Blome et al., 2013). A system can be a flexible without being agile, whereas an agile system should be flexible. The flexibility is defined as "the ability to modify the range of tactics and operations to the extent needed" (Gligor et al., 2013, p. 97). The prior SC agility studies identified the importance of flexibility in offering an agile response (Braunscheidel and Suresh, 2009). Some studies viewed flexibility as an aspect of SC agility (Li et al., 2008, 2009). Agarwal et al. (2007) noted that agility is obtained by tapping the synergies amongst various forms of flexibility within a firm. Swafford et al. (2006) conceptualised SC agility as an externally focused capability which is derived from flexibility (which is internally focused competency) is SC processes. They viewed flexibility-agility to have a competence-capability relationship. Interestingly, Swafford et al. (2008) found that SC flexibility has a positive impact on SC agility. Similarly, Chiang et al. (2012) revealed that firm's strategic flexibility is significantly related to the firm's SC agility.

#### (8) Lead Time Reduction

Customers demand ever-shorter delivery times and lead time reduction so as to synchronise supply during the peaks and troughs of the demand (Agarwal et al., 2007). Delivery speed is defined as the ability to deliver products or services faster than rivals,

whilst lead time reduction is an elapsed time from order to delivery as a mechanism for time-based competition (Agarwal et al., 2007). Some definitions of SC agility tend to focus on speed, quickness, and measure of reaction time (Swaifford et al., 2008; Li et al., 2008). Swaifford et al. (2006) put forward the measurements of SC agility by including how quickly a firm can reduce manufacturing lead times and delivery time. Christopher (2000) also ascertained that agile attributes are transformed into strategic competitive bases of speed.

#### (9) Change Alertness

Knowledge management scholars have emphasised that agility should go beyond by recognising the need for alertness as a constituent of agility (Li et al., 2008). Alertness is defined as "the ability to quickly detect changes, opportunities, and threats" (Gligor et al., 2013, p. 95). Li et al. (2008) firstly conceptualised alertness as a dimension of SC agility. They contended that agile SCs should be alert to changes within the SC and within the surrounding environment by sensing emerging market trends, interacting with customers, and monitoring the demand for daily point-of-sale data. Their SC agility indicated the firm's SC to be alert and respond to changes at strategic, operational and episodic levels. Li et al. (2009) noted that the component of alertness can be seen as an opportunity-seeking capability from both internal and external point of view.

#### (10) Communication Channels

Communication channels via IT create opportunities for augmented SC agility (Swaifford et al., 2008). The increasing use of IT creates virtual SCs (Christopher, 2000). Virtual SCs are based on information instead of inventory. Real-time technology system is vital to enable manufacturers to boost their SC agility by effectively gathering, storing, accessing, sharing and analysing data. By means of Electronic Data Interchange (EDI) and the Internet, companies can share the pertinent data such as information flow, physical flow and financial flow with their SC partners (Swaifford et al., 2008). In this way, it helps to mitigate the risk of demand distortion and variance amplification, which might lead to a bullwhip effect.

### **INTERPRETIVE STRUCTURAL MODELLING**

Interpretive structural modelling (ISM, hereafter) is a process to graphically demonstrate interrelations between elements in a complex system. Complexities stem from tangled interactions among elements, but not all of them are interconnected, therefore pinpointing existence of specific relations will be critical to understanding the holistic picture of a system. ISM provides a sequential process to reach this holistic understanding by scrutinising interrelations between two elements as well as their indirect effects on other elements.

ISM process to analyse the enablers of SC agility consists of seven steps.

- (1) Identification of enablers: Elements that comprise a complex system are identified. This study used literature review and discussions with practitioners to identify 10 enablers of SC agility. Each enabler was numbered for easier analysis in the process.
- (2) Contextual relationships between enablers: The relationships between two elements are decided. This study checked contextual relationships by asking practitioners whether element A leads to element B. A total of 45 pair-wise relationships was confirmed by practitioners.
- (3) Developing a structural self-interaction matrix (SSIM): SSIM puts pair-wise contextual relationships together in a single matrix by using symbols like V (i leads to j), A (j leads to i), O (no relationship) and X (i leads to j while j leads to i).
- (4) Developing a reachability matrix: An initial reachability matrix converts the symbols in SSIM into binominal 0 (i doesn't lead to j) and 1 (i leads to j). A final reachability matrix considers transitivity of elements: if i leads to j and j leads to k, the relationship between A and C denoted 1 although there was no direct relationship between A and C.
- (5) Partitioning levels of enablers: Based on the final reachability matrix, each enabler will have a reachability set (Rs), an antecedent set (As) and an intersection set (Is). If an

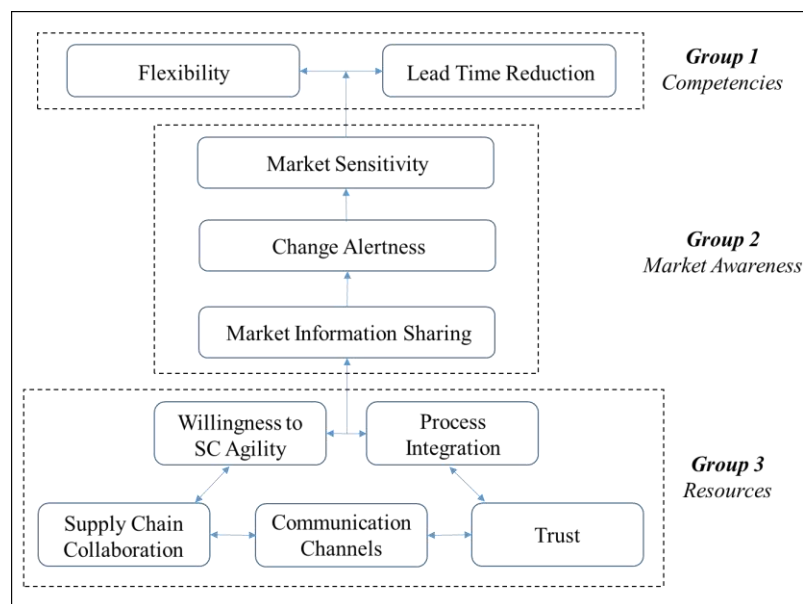
enabler's Rs is the same as Is, this enabler will be allocated to the first level and then deleted from the existing sets. The same iteration will be continued for level partitioning.

(6) Drawing a digraph: A digraph (directed graph) can be drawn by aligning enablers according to the level partitioning, and then by connecting them using an initial reachability matrix. No transitivity will be considered because this graph will show direct relationships.

(7) Finalising an ISM-based model: An ISM-based model can be completed by replacing numbers for analysis with their original element titles. The model is verified and further discussed to understand the enablers of SC agility in a holistic manner.

## RESULTS

The ISM based model has been developed by the aforementioned ISM process. As can be seen in Figure 1, this model showed three groups of enablers which can be interpreted as agility competencies (Group 1), market awareness (Group 2) and resources (Group 3).



**Figure 1. ISM-based model of SC agility enablers**

By definition, agility is the capability to respond to the changes in a timely and flexible manners (Li et al., 2008). Timely responsiveness can be translated in the FMCG industry as lead time reduction; compression of order-to-delivery cycles or manufacturing cycles to effectively deals with short life cycles of products. Flexibility can make FCMG firms to change their tactics and operations easily (Gligor et al., 2013), thereby increasing responsiveness. Flexibility and lead time reduction are mutually interrelated.

Although flexibility and lead time reduction are key competencies for agility, the directions of these will be decided by market awareness. When it is considered that agility aims to achieve a pull strategy based on market requirements, market awareness determines the strategic directions of agility competencies. Basically, market awareness starts from market information sharing between industry partners, which in turn generates change alertness in the market environments. Then, market sensitivity is fostered to read and respond to demand changes. These are key ingredients of agility in FMCG industry whose market is rapidly changing even within several months.

Some inter- and inter-organisational resources will be required to build market awareness. These resources are all interconnected by creating a big feedback loop which self-enhances themselves. For instance, willingness to SC agility is a corporate culture to achieve agility in a FMCG firm. This willingness can lead to process integration within the firm and with suppliers and customers. A fully-integrated process can help goal alignment and mutual understanding of the businesses, thereby generating supply chain collaboration and trust between firms. Various and effective communication channels will be used to maintain

these, whilst communications can fortify trust and collaboration as well. Willingness to SC agility can be also stimulated and developed by the confidence in trust and collaboration.

## CONCLUSION

This study found that enablers for SC agility are highly interrelated to each other. Willingness towards SC agility and communication are identified as bottom-level factors in the ISM hierarchy and thus viewed to be key drivers in achieving SC agility, whereas flexibility and lead time reduction are considered as top-level factors that depend on other factors to acquire SC agility. FMCG manufacturers should pay attention to fundamental resources to support the agility; the willingness to SC agility and communication since both key drivers help to improve process integration, SC collaboration, communication channels and trust. These factors help in turn to enhance the alertness to changes which has a positive impact on market sensitivity. Together with market sensitivity, structured and defined processes and continuous improvement can increase flexibility and lead time reduction which finally results in more agile SCs.

The finding indicates that SC agility depends on flexibility, lead time reduction and alertness due to their strong dependence on other factors but comparatively weak driving power. Hence, German FMCG manufacturers should adopt additional strategies to augment these three factors. Besides, it was found that willingness to SC agility, communication, SC collaboration, trust, structured and defined processes and continuous improvement are strong drivers of SC agility. In particular, communication and willingness to SC agility need to be highlighted in this regard as both factors are bottom-level factors in ISM hierarchy which explain the importance of a high driving power and low dependence. It would be plausible that German FMCG manufacturers need to maintain a high level of communication and willingness to SC agility.

Despite the contribution of this research, it contains some limitations. First, the elements were selected through group discussions of selected participants, so the selection may have some biases. Second, this study solely focuses on the FMCG industry, thus, its finding is limited to this sector. The same applied to the country (Germany). Third, the cross-sectional research design illustrates a snapshot and thereby limits the horizon of the research. The future research may conduct a longitudinal study.

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# **DEVELOPMENT OF A FUZZY DECISION SUPPORT SYSTEM FOR FORMULATING A FLEXIBLE PRICING STRATEGY FOR DYE MACHINERY UTILIZATION**

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## **Abstract**

### **Purpose of this paper:**

Dye processing incurs a heavy portion of operating costs, such as overheads, machine depreciation, machine maintenance, water treatment plant and the cost of fuel. Various practices have been developed by practitioners in the dye industry in an attempt to reduce costs. One approach is to give discounts to avoid being under-booked, and such practice also helps to lure customers away from competitors. However, obstacles are found in formulating a flexible pricing strategy, taking into consideration a number of factors that can affect the current dyeing price. Therefore, this paper develops an adaptive fuzzy system for formulating a proper, flexible pricing strategy under the fast-changing conditions of the variable factors involved.

### **Design/methodology/approach:**

An adaptive fuzzy system, which incorporates fuzzy logic and database management, is proposed. A proper discount rate is generated by the proposed fuzzy-based system. The results are used as feedback to continuously improve the system, thereby helping the dye industry to remain competitive and minimize potential profit losses.

### **Findings:**

The proposed system is validated through a pilot study in a case company. Preliminary results reveal that with automated and optimized dye processing pricing for the customer, the utilization of dyeing machinery increases, which in turn reduces the average fuel usage per order, as well as increasing the profit gained for the dye house.

### **Value:**

This paper fills the gap in the literature in which decision support for the pricing strategy of dye practitioners was rarely discussed. Through actively assessing the economic cycle to adjust the discount rate and a continuous model for pricing strategies adjustments, this concept is applicable to other industries within supply chains, especially for manufacturers with high operating costs.

### **Research implications:**

In supply chain and manufacturing sectors, utilization of process and equipment is often a big issue to industry insiders. This paper discusses the essence of decision support for the formulation of pricing strategy for manufacturers. Researchers are suggested to further investigate the pricing issue of the entire supply chain and a specific industry.

## **INTRODUCTION**

Garment dye processing incurs a heavy portion of operating costs, such as overhead, machine depreciation, machine maintenance, water treatment plant and the cost of fuel just to get the boilers started. Various practices have been developed in the dye industry in an attempt to reduce costs. One approach is giving discounts to avoid being under-booked. It is a common practice in the airline industry to give discount tickets for booking in advance, so that empty seats of flight can be filled, minimizing potential heavy losses. A similar practice is followed by dye industry practitioners. In order to maximize the utilization of dye machinery, discounts are given at different time intervals. Such practice, on the one hand, utilizes the available capacity of the dye machines for production, and on the other hand helps lure customers away from competitors.



The decision for justifying an appropriate discount rate for dye processing service, which is made by top management, however, is not easy to make without comprehensive domain knowledge and experience within the industry. Numerous factors are taken into serious consideration in determining an appropriate discount rate in order to strike a balance between the goal of booking capacity utilization of dye machines and profit maximization of the service. Currently and conventionally, there is a lack of decision support to aid dye practitioners in the formulation of a flexible pricing strategy for the dynamic and ever-changing demand for dye processing service. Therefore, in this paper, a fuzzy decision support system, which incorporates fuzzy logic and database management for formulating an appropriate, flexible pricing strategy under the fast-changing conditions of the variable factors in effective determination of the discount rate, is proposed.

## **LITERATURE REVIEW**

Pricing decisions regarding dyeing service is a critical decision to make in order to achieve the goal of maximizing the profit while utilizing the available dye machinery capacity and retaining pricing competitiveness. Such decisions are usually made by top management of dye houses who have extensive domain expertise and insight on the long term development trend within the dye and textile industry. However, the management side of dye companies is rarely discussed in the mainstream literature. Previous studies mainly focused on the operational aspects of the dye and textile industry. In particular, researchers emphasized on minimizing the environmental effects of dyeing operations through, for example, wastewater treatment (Han et al., 2009; Pearce et al. 2003; Ong et al., 2014) and decolourization of dyes in the textile industry (Abadulla, 2000; Banat, 1996; Srinivasan and Viraraghavan, 2010; Saratale et al., 2011). Previous studies related to the pricing decision support of dyeing service are inadequate. Without appropriate decision support, decisions made by top management of dye houses greatly relies on the decision maker's domain knowledge and justification. The quality of the decision as well as the efficiency of decision-making cannot be guaranteed.

Despite the absence of decision support systems in the dye industry, a number of studies are found, introducing artificial intelligence techniques for providing decision support in other fields. He et al. (2003) suggested a bidding strategy for autonomous agents in continuous double auctions using the fuzzy logic technique; Lin et al. (2011) introduced an agent-based web application for automatic price negotiation using a fuzzy expert system; Amjady (2006) developed a price forecasting system of the electricity market using fuzzy neural network; Kuşan et al. (2010) used fuzzy logic for predicting house selling prices. Fuzzy logic has been one of the most popular methods to capture and represent vague and uncertain domain knowledge in the literature (Coşgun et al., 2014). It has been a common approach for effective prediction of demand and prices, and has also been applied to solve a wide range of various engineering problems (Ross, 2017). Having the ability of modelling imprecise and qualitative human knowledge by using fuzzy "IF-THEN" rules to generate a mapping from fuzzy sets in the input universe of discourse to fuzzy sets in the output universe of discourse (Ustundag et al., 2010), fuzzy rule-based system allows us to emulate the human reasoning process and make decisions based on imprecise and qualitative information or data (Coşgun et al., 2014).

In view of the necessity of providing decision support in the dye industry, this paper fills the gap in the mainstream literature by developing a decision support system for enabling dye houses to effectively formulate a pricing strategy that is price competitive, and at the same time utilizing the available capacity of the internal dye machinery. The proposed system integrates the fuzzy logic technique, a technique that is proven to be effective in determining or forecasting prices or demand.

## **ARCHITECTURE OF FUZZY LOGIC-BASED SYSTEM FOR DYE SERVICE PRICING DECISION SUPPORT**

A fuzzy logic-based dye service pricing system (FDSPS) is proposed. The architecture of FDSPS is shown in Figure 1. For the fuzzy logic technique to be applied for providing decision support in determining a proper discount rate in the dynamic and changing dye service external business environment, while taking the current internal dye machinery available capacity into consideration, FDSPS consists of two modules: (i) Historical information processing module and (ii) Dye service pricing decision support module.

### **Historical information processing module**

In determining a proper discount rate to be given to customers, dye practitioners take several factors into account. These factors can be classified into two aspects: the external environment and the internal resource availability. To provide decision support for discount adjustment, FDSPS requires historical information over the past 12 months, such as planned booking capacity, actual utilization of dye machinery, and discounts given each time period. Due to the need for processing a large amount of historical data for identifying the present situation under all external and internal factors that influence decision-making in dye service pricing, a centralized database is required to store the historical data in one united place. Such information can be inputted manually, or directly retrieved from sources such as the enterprise resource planning (ERP) system, the customer relationship management (CRM) system, and previous sales reports. For the stored historical data to serve as the inputs to the fuzzy inference system in the dye service pricing decision support module of FDSPS, the data are sorted and extracted from the centralized database in this module. Data transformation and calculation is required to convert the data into usable and useful parameters for determining the fuzzy characteristics of the parameters, including the fuzzy terms, membership functions, and fuzzy rules.

### **Dye service pricing decision support module**

The transformed, calculated data are extracted from the previous module for knowledge acquisition and fuzzy characteristics adjustment in this module. The pricing decision maker, preferably the person with domain expertise and knowledge on formulating proper pricing strategy of dye service, can adjust the fuzzy sets during the fuzzification step, so that the factors in discount determination are transformed into fuzzy regions and membership functions. Due to the dynamicity of the dye and fashion industry, the proposed system is to be developed with human intervention capability to enable operators to adjust the fuzzy regions of each fuzzy input whenever necessary.

With the defined fuzzy inputs and membership functions, they are passed to the fuzzy inference engine for fuzzy rules generation. These fuzzy rules are a set of "IF-THEN" rules serving as logical representation of the relationships between the input and output parameters of FDSPS. They are defined by the top management of the dye house who made the pricing decisions with a considerable level of domain experience and knowledge, and are stored in the knowledge repository engine of FDSPS. Upon the completion of configuring fuzzy inputs in the fuzzification step, and creation of logical fuzzy rules for systematic representation of input-output relationships, the process of defuzzification can proceed, so that the output fuzzy sets are defuzzified for the conversion from fuzzy sets to crisp values. The output of FDSPS, which is the suggested discount rate for the dye service to be given in the upcoming month, assists dye practitioners in justifying an appropriate discount for customers who are going to pre-book the dye service, with the external environmental factors, i.e. actual booking capacity as the demand indicator, and internal resource availability, i.e. utilization of dye machinery, being taken into consideration by converting them into measurable fuzzy inputs and outputs.

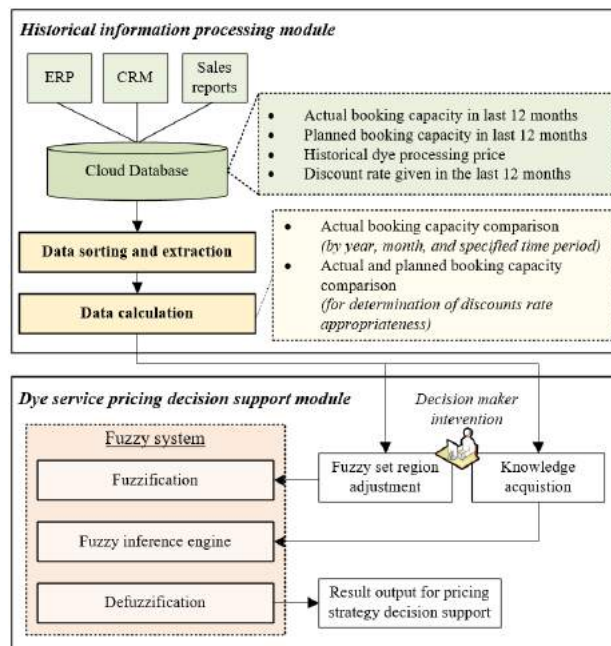


Figure 1. Architecture of FDSPS

## CASE STUDY

A prototype of FDSPS is implemented in Zhongshan Newbond Textiles Limited (Newbond), a China-based company with factory operating since 1992. The company is under the Winzen Group, a Hong Kong based company, founded in 1956. The Winzen Group offers garment manufacturing, fabric and dyeing services. The case company is the arm that specialises in dyeing services. To remain competitive, there is a need for higher quality and faster delivery time. The niche for further productivity improvement in the traditional enterprise resource planning (ERP) system is reaching its limits. For further productivity improvement, the firm believes that efforts should be paid in areas such as automation, Artificial Intelligence, Industry 4.0, etc.

## Existing challenges faced by the case company

Due to the limited capacity of the dye machinery and increasing cost in dye processing, the case company experienced a certain level of difficulty in quoting a proper price at the start of each month. Conventionally, their pricing decision is made by top management who have years of experience in the field of dye industry. However, heavy reliance on domain expertise in decision making is unbeneficial to the sustainable development of the firm. Therefore, with the aim of maintaining and improving the quality of decision making so as to yield long-term benefits for the company, Newbond has decided to pilot the FDSPS for obtaining decision support in making regular pricing decisions in dye service.

## Implementation of FDSPS

An implementation roadmap is designed for the development of FDSPS. It is classified into four major milestones, they are: (i) Database construction, (ii) Fuzzy system development, (iii) Back-end technical integration and front-end user interface development, and (iv) Pilot testing and fine-tuning.

### (i) Database construction

Historical data available from various sources, such as the ERP, CRM system and sales reports, are gathered and stored in a relational database. Data sorting and extraction algorithms are developed for mining relevant information, such as the planned and actual booking capacity in the past 12 months. Extracted data are converted into useful information through data calculation, which are then transmitted to the fuzzy system for fuzzy characteristics adjustments, so that the quantitative values of the membership function of each fuzzy input parameter can be updated.

(ii) *Fuzzy system development*

The development of the fuzzy system, which is the core component of FDSPPS for providing pricing decision support, comprises three essential steps, they are: Fuzzification, Fuzzy inference system, and defuzzification.

● *Fuzzification*

For fuzzification, factors for determining dye service pricing are identified from discussions and interviews with domain experts and top management of the case company, who make the final pricing decisions regularly. These essential factors are converted into fuzzy input sets for the proposed FDSPPS to generate the appropriate output, that is, the recommended discount rate of the dye service to be given to customers in the coming month. There are three fuzzy input sets, namely, demand period identification, month-to-month booking capacity comparison, and comparison between predicted and actual booking capacity. Relevant data extracted from the cloud database is calculated for defining the reasonable ranges of the membership function of each fuzzy input parameter. The general equation of an input fuzzy set is shown in equation (1).

$$A = \sum_{i=1}^n \frac{\mu_A(a_i)}{a_i} \quad (1),$$

where  $A$  is the whole data set, and  $a$  is an element of subset  $A$ . Details of defining membership function of each fuzzy input are discussed below. A summary of the input and output parameters of dyeing service pricing generated in FDSPPS is depicted in Table 1. For ease of illustration, assume currently we are in month  $Y$ , at year  $X$ , with the latest booked capacity of dye machinery denoted as  $B_{X,Y-1}$ . The output is the discount rate to be given in the coming month (denoted as  $D_{X,Y}$ ), so that the actual booked capacity ( $B_{X,Y}$ ) can reach our targeted one, i.e.  $P_{X,Y}$ .

For the first fuzzy input, i.e. demand period identification, the latest total booked capacity of the dye machinery ( $B_{X,Y}$ ) is benchmarked with the demand pattern in the past 12 months. The membership functions of this fuzzy input therefore make use of the actual booked capacity at the first day of each month in the past 12 months to determine the range of membership functions being classified as Trough, Normal, or Peak demand period.

For the second fuzzy input, i.e. month-to-month booking capacity comparison, the actual booked capacity for month  $Y-1$  at year  $X$  is compared with that for month  $Y-1$  at year  $X-1$ . In other words, a comparison between  $B_{X,Y-1}$  and  $B_{X-1,Y-1}$  is made. Through such month-to-month comparison, the decision maker is able to realize the sales performance up to the last month to justify if the discount rate to be given in the coming month requires an adjustment.

For the third fuzzy input, i.e. comparison between predicted and actual booking capacity, the value of  $P_{i,j}$  and  $B_{i,j}$  is compared, in which  $i$  and  $j$  are the specified year and month respectively. The obtained value provides an indication of whether the current discount given is "too little", "too much" or "on target". Considering that the case company allows customers to reserve the dyeing services three months in advance, two comparisons are necessary for determining whether there is too much or little discount given, they are:  $P_{X,Y-1}$  and  $B_{X,Y-1}$ , and  $P_{X-1,Y-3}$  and  $B_{X-1,Y-3}$ . A general equation to compute the relative difference ( $d_{i,j}$ ) between  $P_{i,j}$  and  $B_{i,j}$  is shown in equation (2). The average value of the two comparisons ( $D_{X,Y}$ ) is the input value of this fuzzy set, where the computation is displayed in equation (3).

$$d_{i,j} = \frac{P_{i,j} - B_{i,j}}{P_{i,j}} \times 100\% \quad (2),$$

$$D_{X,Y} = \frac{d_{X,Y-1} - d_{X-1,Y-3}}{2} \quad (3),$$

Table 1. A summary of the parameters in the fuzzy system in FDSPS

Parameters [Symbol]		Fuzzy class	Membership function	Shape	Type*
Inputs	<b>Demand period identification [D]</b>	Trough	[0, 10, 20]	Triangle	Dynamic
		Normal	[10, 20, 80, 90]	Trapezoid	Dynamic
		Peak	[80, 90, 100]	Triangle	Static
	<b>Month-to-month booking capacity comparison [M]</b>	Worse	[-20, -20, -5, 0]	Trapezoid	Static
		Same	[-5, 0, 5]	Triangle	Static
		Better	[0, 5, 20, 20]	Trapezoid	Static
	<b>Predicted and actual booking capacity comparison [P]</b>	Too little	[-20, -20, -5, 0]	Trapezoid	Static
		On target	[-5, 0, 5]	Triangle	Static
		Too much	[0, 5, 20, 20]	Trapezoid	Static
Output	<b>Change in discount rate to be given in the coming month [C]</b>	Significantly decrease	[-1, -0.67, -0.33]	Triangle	Static
		Slightly decrease	[-0.67, -0.33, 0]	Triangle	Static
		No change	[-0.33, 0, 0.33]	Triangle	Static
		Slight increase	[0, 0.33, 0.67]	Triangle	Static
		Significantly increase	[0.33, 0.67, 1]	Triangle	Static

\*Dynamic indicates that the membership function values are re-calculated and re-adjusted every time.

#### ● Fuzzy inference system and defuzzification

The defined input fuzzy sets in the previous stage, as summarized in Figure 2, together with a set of "IF-THEN rules", which is stored in the knowledge repository, are used for the construction of the fuzzy inference system in FDSPS using the MATLAB® fuzzy logic toolbox. Some examples of these rules are shown in Table 2. With the input and output parameters, and the fuzzy rules configured, the output, that is, the discount rate to be given in the coming month for dye service, can be generated, providing decision support for top management to provide an appropriate and reasonable price for dyeing service.

Table 2. Example of "IF-THEN" fuzzy rules

Rule 1	
IF	<i>The current demand IS <b>Trough</b> period AND</i>
	<i>Month-to-month booking capacity comparison IS <b>Worse</b> AND</i>
	<i>Predicted and actual booking capacity comparison IS <b>Too little</b> AND</i>
THEN	<i>Change in discount rate to be given in the coming month IS <b>Significantly increase</b></i>
Rule 2	
IF	<i>The current demand IS <b>Normal</b> period AND</i>
	<i>Month-to-month booking capacity comparison IS <b>Better</b> AND</i>
	<i>Predicted and actual booking capacity comparison IS <b>On target</b> AND</i>
THEN	<i>Change in discount rate to be given in the coming month IS <b>Slightly decrease</b></i>

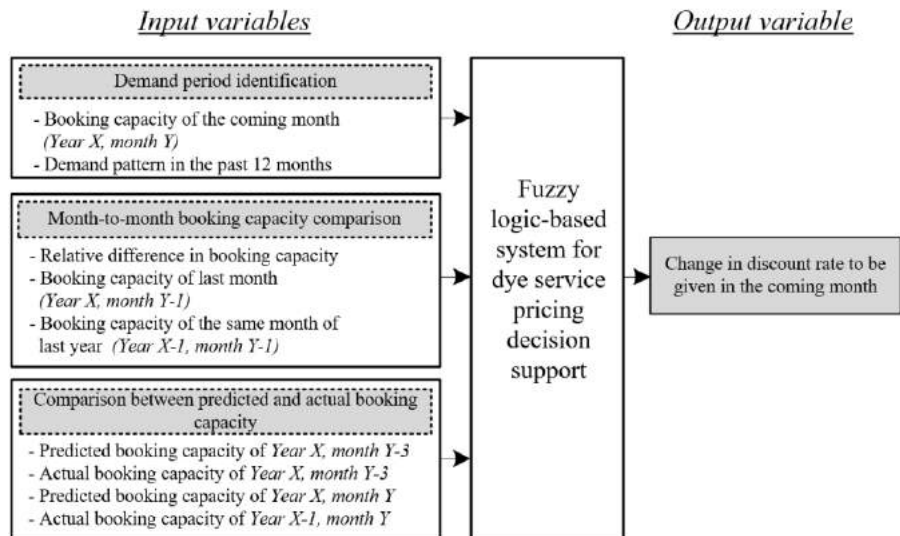


Figure 2. Input and output parameters of the fuzzy inference system

## RESULTS AND DISCUSSION

Upon implementation of the prototype of FDSPS in Zhongshan Newbond Textiles Limited, the improvement in the decision-making of pricing strategy of dyeing service has been significant, particularly in terms of efficiency of making decisions. With the adoption of FDSPS, top management of the case company no longer solely relies on managers, even with rich knowledge and experience, to determine a proper price tag of their dyeing service. FDSPS enables systematic generation of a reasonable price so that a person who is lacking in adequate experience in the field could also make a wise decision. An example of the result generated by FDSPS, as shown in Figure 3, illustrates the suggested discount rate to be given in the coming month with the following input values: (i) A current booked capacity of 15%, (ii) a negative 2.8% relative change of booked capacity in a month-to-month comparison, and (iii) a negative 0.6% relative difference between predicted and actual booking capacity. These values of input give a suggested 23.6% increase in the discount rate to be given in the coming month in order to meet the sales target while utilizing the available dye machinery resource capacity. By the systematic transformation of knowledge and the experience-driven pricing decision of dyeing service into quantitative inputs and outputs through the incorporation of the fuzzy-based system, managers who quote prices to their customers regularly take into account the suggested discount rate generated by FDSPS, thereby realizing human intelligence in the perspective of strategy formulation in managing a dye house.

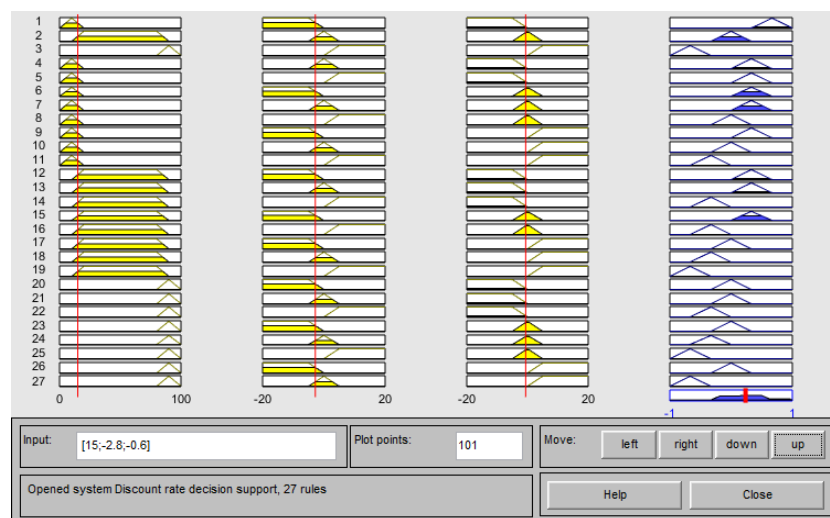


Figure 3. Result obtained using FDSPS

## CONCLUSIONS

Dyeing service pricing is a decision which heavily relies on human knowledge and experience make. With a lack of IT or artificial intelligence aiding decision support, a dye house's profit and loss hinges on the decision makers' justification and experience in the dye industry. Factors influencing the amount of discount to be given to the B2B customers, as well as the way of thinking and determining a proper price tag for dyeing service, are abstract terms. Although there is a certain difficulty to transform all intangible factors into measurable units, this paper attempts to trim down and quantify the most critical factors influencing dyeing service pricing decision-making. This paper presents a fuzzy decision support system, which incorporates fuzzy logic and database management for effective formulation of a flexible pricing strategy under the fast-changing environment in the dye and textile industry. The results show that a dye house can reduce the heavy reliance on decision maker's domain expertise in adjusting the dyeing service prices.

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# **EXAMINING CUSTOMER-SIDE SUPPLY CHAIN QUALITY MANAGEMENT UNDER THE DIGITAL ERA**

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## **Abstract**

### **Purpose:**

Since 2009, China has become the world's largest automobile producer and market. However, there is limited Supply Chain Quality Management (SCQM) research of China, which renders SCQM understanding insufficient in explaining the globalised supply chain. Additionally, the literature focuses more on internal and supplier-side SCQM but not pay enough attention to the customer-side SCQM. However, SCQM is a customer-driven management philosophy (Robinson and Malhotra, 2005). The recent development of digital technology has also assisted automobile manufacturers to collect more real-time customer information that can lower development costs and speed up the time to market. Thus, it is meaningful to revisit customer-side SCQM between Chinese Self-owned Brands (CSBs) and Joint Ventures (JVs) in the Chinese automobile industry. This research aimed to answer three research questions: RQ1): What are the main factors impacting on SCQM in the Chinese automobile industry? RQ2): What are the differences between CSBs and JVs in implementing the most significant SCQM factor? RQ3): Why do such differences occur?

### **Design:**

A mixed research method was implemented. The researchers collected 196 valid replies back by employing a survey. Partial Least Squares was chosen as the analysis method, and the assessment procedures from Hair et al. (2014) were implemented. Following the survey, six follow-up interviews were conducted to identify the reasons for different customer-side SCQM application between CSBs and JVs.

### **Findings:**

This research identifies that customer-side SCQM is the most significant SCQM factor of improving operational performance. It recognises that ownership does influence the relationship between customer-side SCQM practices and performance. Furthermore, it summarises that the role of dealers, as well as the application of digital technology in CSBs and JVs are the causes of different customer-side SCQM implementation.

### **Value:**

The findings assist academics in gaining a deeper understanding of the key relationships between SCQM practices and performance. The comparative study between CSBs and JVs expands the SCQM theory by clarifying the different customer-side SCQM practices under the digital era. Furthermore, this study answers the calls for ownership and emerging market research in SCQM.

### **Research Limitation:**



Due to the limited access, this research only compared CSBs and JVs. The imported brands that also play important roles in the Chinese automobile industry should be included in the future study to add more depth into comparisons.

### **Practical Implications:**

This research enhances the understanding of quality and supply chain managers about the best SCQM practices. With the development of information technology and the change of customer's consumption habit, automakers should start to adjust their customer-side SCQM by shortening the distance to customers and applying more digitalized cooperation practices.

### **INTRODUCTION**

According to data from the China Association of Automobile Manufacturers (CAAM, 2015), automobile production in China increased from 9.3 million in 2008 to 23.7 million in 2014. Besides the large amount of total production, China also has the most competitive automobile market in the world, which includes more than 100 brands and 300 models. These brands can be categorised into three groups: Chinese Self-Owned Brands (CSBs), Joint Venture Brands (JVs), and Imported Brands (IBs). CSBs are purely controlled by Chinese firms. For instance, HongQi and Haval are common examples in the Chinese market. JVs are jointly established by Chinese firms and foreign companies, in which the foreign company cannot exceed 50% of the brand ownership. For instance, FAW-Volkswagen is a Chinese-German JV. IBs represent the cars that are assembled in foreign countries and which are then exported to China. Infinity and Jaguar are common examples on Chinese roads. Moreover, the Initial Quality Study (IQS) of JD Power indicates that there are 23 brands whose quality is above the mass market average level in China (JD Power, 2015). There are only four CSBs exceeding the market average quality level compared to 15 JVs and four IBs. The number of four CSBs is an unsatisfactorily small number compared to the total brand quantity in the Chinese market. It shows that the quality of CSBs is still lagging other competitors, especially the JVs.

Further, the digital technology is creating an increasing level of connections between digital devices and online services. This significantly changes customers' consumption habit. Based on the report of Accenture (2015), 75% of its survey respondents would consider conducting the entire car purchase online. McKinsey (2015) also claimed that the share of customers willing to switch their car brand for better connectivity has increased from 20% in 2014 to 37% in 2015. This phenomenon is more obvious in China. Accenture (2015) identified 53% of Chinese consumers stated that they would buy a car online; 60% of Chinese customers are willing to switch their car brand for improved connectivity (McKinsey, 2015). Hence, to better understand Chinese customers' expectation, automakers should not only focus on the cooperation with the traditional dealers but also generate an efficient strategy to satisfy customer by utilizing digital channels.

Although Supply Chain Quality Management (SCQM) has gained attention in the academic arena, the research effort in theory construction of SCQM is nevertheless insufficient. In recent years, some related studies have discussed SCQM (Robinson and Malhotra, 2005; Foster, 2008; Kuei et al., 2008). However, they aimed at identifying SCQM, citing the expected benefits in conducting SCQM, and proposing the implementation paths. Little empirical effort has been made to compare the different SCQM practices among organisations especially in emerging markets and to identify the causes of the differences. In summary, the research gaps are consolidated and presented as follows. Firstly, the studied SCQM practices and performance are incomplete because most previous research has focused on the company internally or upstream Supply Chain (SC) (Zeng et al., 2013). Secondly, compared to the SCQM study that focused on developed economies, there is a lack of SCQM studies that investigate emerging economies especially China, the role of which turn out to be extremely important in the global market (Foster, 2008). Moreover, for the studies that investigated the Chinese automobile industry, no study has focused on

SCQM from the perspective of CSBs. To fill these two gaps, this research aims to compare CSBs with JVs which have established manufacturing operations in China by analysing the SCQM practices and performance that are generated from a specifically designed SCQM framework. Three Research Questions (RQs) are proposed and will be answered: RQ1): What are the main factors impacting on SCQM in the Chinese automobile industry? RQ2): What are the differences between CSBs and JVs in implementing the most significant SCQM factor? RQ3): Why do such differences occur?

## **THEORETICAL BACKGROUND AND HYPOTHESES**

The SC of the automobile industry is growing longer and more complicated because of the involvement of a vast number of components and the high degree of participation of suppliers and dealers in the business. To assure the quality of the complicated SC, Quality Management (QM) should be extended to the SC context because most products are designed, manufactured, and delivered through complex SC networks, with SC partners located in different geographical regions (Kaynak and Hartley, 2008). Therefore, instead of focusing only on their organisational quality management, organisations must extend their vision and efforts of quality improvement to the whole of the SC (Foster, 2008). As a result, QM has become more SC-oriented (Huo et al., 2014).

Robinson and Malhotra (2005) then argued that based on all SC participants' efforts, SCQM is the integration of business processes to measure, analyse, and continually improve product, service, and process. Similarly, Kuei et al. (2008) also highlighted the process-centric nature of SCQM. They clarified that SCQM, which designs quality into SCs, optimises the materials flow, stabilises SC-level quality systems, and maximises the seamless data sharing, is an effective approach to the new business pressures (e.g. outsourcing, SC relationships). Moreover, SCQM is also a strategic philosophy that aims to satisfy customers by utilising the close SC upstream and downstream relationships (Foster, 2008). The strategic collaboration with all the SC partners is one of the critical success factors of SCQM implementation (Foster, 2008). Therefore, based on these critical characteristics, SCQM is defined as follows in this study: *'an SC-wide approach that systematically utilises cooperation to analyse, stabilise, and continually improve the quality of the processes and offerings (products and/or services) to satisfy internal and external customers'*. Hence, the SCQM practices not only include company-wide QM but also contain supplier and customer side SCQM. SCQM performance is a subset of the overall concept of organizational effectiveness, which contains both financial and operational performance.

Companywide QM recognises that all the departments and employees within a firm should conduct quality-related activities as part of an integrated process (Flynn et al., 2010). Companywide QM links all the quality practices that operated within the organisation into a seamless process to meet and exceed customers' expectation. It emphasises cross-functional communication and coordination (Huo et al., 2014). These cooperation activities integrate individual departments to a combinative organisation. This helps an organisation recognise and satisfy customers' changing requirements more quickly. Moreover, companywide QM urges the departments to work cooperatively under the same quality policy and pushes everyone in an organisation to take responsibility for QM. It helps to design quality into process, products and services by better sharing and applying the quality information, which leads to better product quality, fewer inventories, and higher productivity (Kaynak and Hartley, 2008). Therefore, the following hypothesis is generated:

**H1a: Company-wide QM is positively related to operational performance.**

Although company-wide QM practices are performed within the company, they are not isolated from its external parties. The experience and knowledge that are generated from company-wide QM can be facilitated by cooperating with and developing relationships with suppliers and customers (Kaynak and Hartley, 2008). Hu and Flynn (2015) clarified that company-wide QM positively affected supplier selection, supplier development, and customer development. Therefore, based on previous literature, the following hypotheses are generated:

**H1b: Company-wide QM is positively related to supplier side SCQM.**

**H1c: Company-wide QM is positively related to customer side SCQM.**

Suppliers play a significant role in achieving effective SCQM by providing intermediate materials (Hu and Flynn, 2015). The effective supplier-side SCQM can reduce differences in the quality of raw materials and parts and ensure that suppliers meet the quality standards. By requiring suppliers to obtain quality certifications, the opportunistic behaviours of suppliers will be decreased and the high-quality product will be ensured (Huo et al., 2014). Hence, the company should effectively cooperate and integrate with suppliers to add the values of suppliers (e.g. suppliers' input of quality improvement) into the final product (Kuei et al., 2008). The development of a solid partnership with suppliers will help them to understand, anticipate, and meet the ever-changing requirements of the buyer. By developing a clear understanding of the buyers' needs, suppliers can help buyers to improve performance (Flynn et al., 2010). Furthermore, the effective supplier relationship management benefits the organizations in obtaining strategic resources and capabilities, thus increasing their competitive advantages. Thus, the following hypothesis is generated:

**H2: Supplier side SCQM is positively related to operational performances.**

The customers' requirement can be systematically satisfied by integrating and collaborating with customers (Zeng et al., 2013). Companies should regularly evaluate customer requirements through surveys, personal meetings, etc. Efforts should also be made to incorporate customer requirements in the product by integrating customer feedback in strategic quality planning (Huo et al., 2014). For example, the results of customer surveys should be regarded as one of the core sources of establishing quality plans. Because customer-side SCQM creates opportunities for utilising the knowledge of collaborative processes, it assists organisations in quickly detecting quality problems and improving operational performance (Flynn et al., 2010). A close relationship between customers and the manufacturer offers opportunities for reducing the manufacturer's product design time and inventory obsolescence and allowing the manufacturer to be more responsive to customer requirements (Flynn et al., 2010). The customer-side SCQM practices that facilitate the collaboration with customers into manufacturers' planning and producing processes improve the manufacturer's employees by creating new knowledge. These downstream SCQM practices also lead to more efficient problem solving because of the cooperation with customers through jointly planning and mutual learning (Swink et al., 2007; Flynn et al., 2010). Therefore, the following hypothesis is generated:

**H3: Customer side SCQM is positively related to operational performances.**

Better quality performance can improve sales, profit, and other market performances through delivering high-quality products, reducing waste, and improving efficiency and productivity (Kaynak and Hartley, 2008). In addition, a smaller inventory can also reduce the holding costs (Huo et al., 2014). Therefore, the following hypothesis is generated:

**H4: Operational performance is positively related to financial performances.**

## **METHODOLOGY**

To answer the 'what (RQ1)', 'how (RQ2)', and 'why (RQ3)', a mixed research methodology has been selected (Yin, 2013). Our study includes two phases. First, a large-scale survey was conducted to investigate the SCQM practices and performance and identify the most significant SCQM factor. Second, the follow-up case studies were carried out to collect more in-depth qualitative data to clarify how CSBs and JVs deal with this factor. Based on the literature review, the questionnaire was designed. The Chinese version questionnaire was generated by back-translation with the help of two practitioners. Based on the feedback from 14 practitioners and one academic during the pilot study, the measurements are appropriate for inclusion and the questionnaire could achieve the research goals. We collected 196 valid replies after six months. Among these replies, 91 were from JVs and 105 were from CSBs. PLS was employed in this study by using SmartPLS 3.0. The measurement model and structural model were examined by following the evaluation process of Hair et al. (2014) and Peng and Lai (2012) to finalize the measurements and

test the hypotheses. We then implemented the follow-up case study to identify the application of the most influential SCQM factor in both CSBs and JVs. We selected six automakers to interview their quality managers. In each company, one interview was conducted. The data analysis process of Miles and Huberman (1994) (i.e. data reduction, data display, and conclusion drawing) was employed.

### MODEL ANALYSIS AND RESULTS

The internal consistency reliability was tested by evaluating CR. The CR values are all above 0.7, which demonstrate acceptable performance (Johnston et al., 2008). Convergent validity was then analyzed by evaluating AVE. The result indicates that AVE scores were all above the recommended value of 0.5 (Hair et al., 2014).

**Table 1: CR and AVE of Reflective Measurement Model**

Second Order Construct	First Order construct	CR	AVE
Company-wide QM	Top Management Commitment	0.900	0.644
	Strategic Quality Planning	0.895	0.682
	Employee Management	0.854	0.595
	Training	0.950	0.825
	Process Management	0.892	0.624
	Product Development	0.863	0.515
	Quality Information	0.926	0.758
	Defect Tracking	0.860	0.673
Supplier Side SCQM	Supplier Cooperation	0.963	0.839
	Supplier Development	0.889	0.669
	Supplier Selection	0.917	0.690
Customer Side SCQM	Use of Feedback	0.932	0.775
	Customer Involvement	0.916	0.685
	Customer Relationship Development	0.780	0.545

Second, the quality of the formative measurements was tested by bootstrapping with 5,000 subsamples.  $R^2$  was evaluated to examine convergent validity. Both operational performance and financial performance have a substantial  $R^2$  value (i.e. above 0.5) (Hair et al., 2014). The variance inflation factor (VIF) was evaluated in the following step to test collinearity. VIF scales are all below 10, which indicates acceptable performance (Neter et al., 1996). Finally, the significance and relevance of outer weight were analyzed by evaluating p values. p values are all smaller than 0.05, which verify their significance in the formative measurement model.

### Structural Model Evaluation

First, Cohen's  $f^2$  was tested to evaluate the effect size of the predicting constructs. Based on Table 2, only H1a's  $f^2$  is smaller than 0.02, which means the predicting power of company-wide QM on operational performance is unsatisfied (Cohen, 1988). Moreover, H1a also has a large p-value (above 0.05). Therefore, this hypothesis is rejected. Other Cohen's  $f^2$  values are all above 0.02, which demonstrates the acceptable effect size of the corresponding hypotheses (Peng and Lai, 2012). By applying the blindfolding procedure, Stone-Geisser's  $Q^2$  value was examined. Stone-Geisser's  $Q^2$  values of all the construct are above 0, which represents the desirable predicting power of the structural model (Peng and Lai, 2012; Hair et al., 2014). Figure 1 shows the SCQM framework in this study. We found empirical support to verify a positive relationship between customer side SCQM and operational performance towards statistical significance ( $\beta = 0.536$ ;  $p = 0.000$ ). It is the strongest relationship between SCQM practice and operational performance, thus demonstrating that SCQM is customer-oriented. It further supports automakers in China emphasize frequently communicating with customers about quality issues through diverse channels, actively involving customers in quality improvement and product design.

**Table 2: Evaluation of Structural Model**

	Path Coefficient	$f^2$	p Value	Decision
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H1a: Company-wide QM → Operational performance	-0.033	0.001	0.771	Rejected
H1b: Company-wide QM → Supply side SCQM	0.852	2.657	0.000***	Supported
H1c: Company-wide QM → Customer side SCQM	0.771	1.469	0.000***	Supported
H2: Supply side SCQM → Operational Performance	0.270	0.039	0.015*	Supported
H3: Customer side SCQM → Operational Performance	0.536	0.228	0.000***	Supported
H4: Operational performance → Financial performance	0.901	4.336	0.000***	Supported

(\*p<0.05; \*\*\*p<0.001)

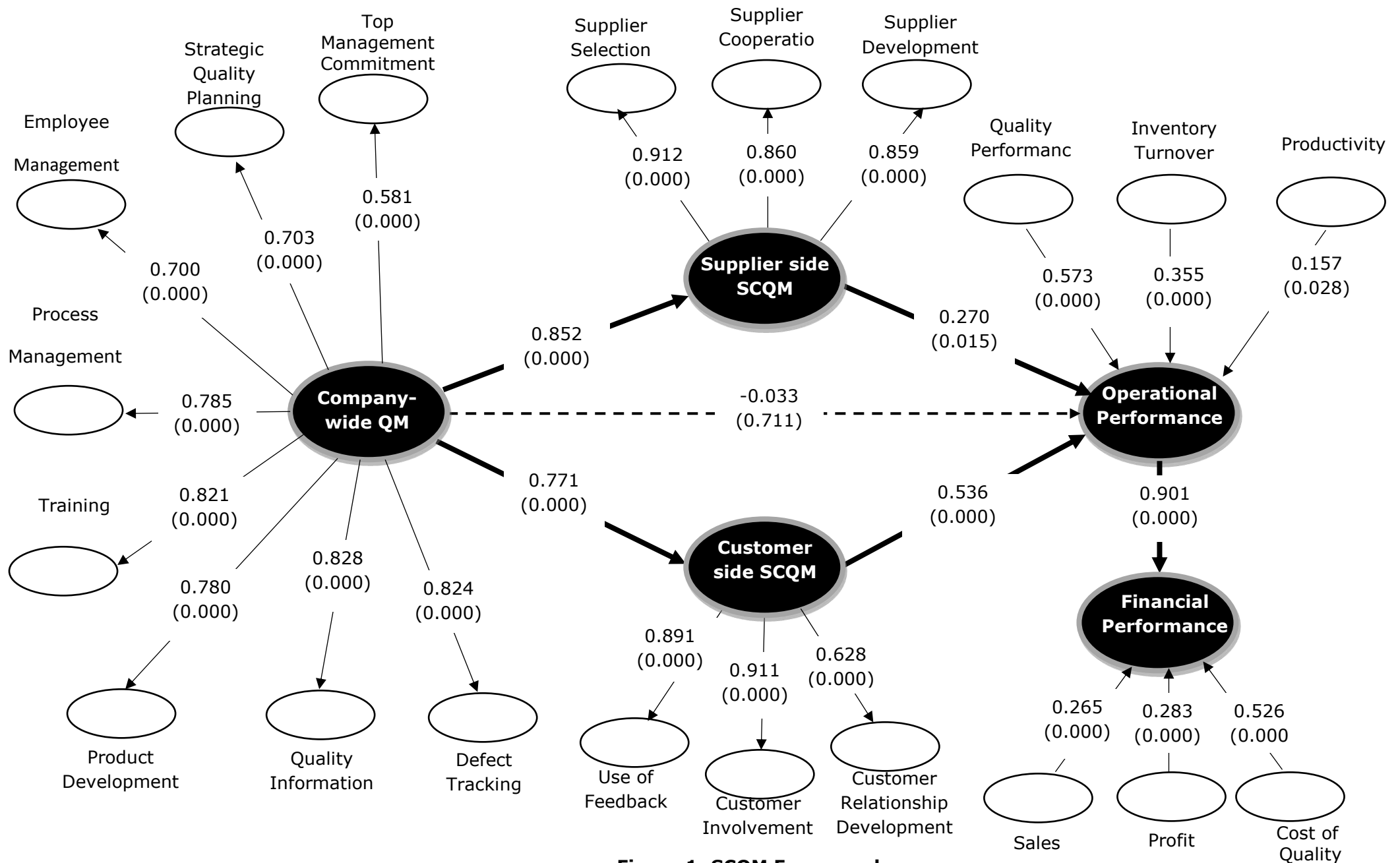
### FOLLOW-UP CASE STUDY

To obtain a deeper understanding of how exactly customer side SCQM works in the Chinese automobile market, we further conducted the case study in six automakers. The detailed information about the participants and the interviews are listed in Table 3.

#### The Relationship between Customer-side SCQM and Operational Performance

Due to the function of CSBs, their dealers are directly communicating with customers. LBX (CSBO2, Quality Manager) explained the decisive role of customer-side SCQM practices in the company: *"The dealer is the core source of customer information, who collects and transmits it to us. If this information is not accurate or delayed, our SCQM will be influenced from the beginning"*. It means that recognising customers' requirements is the first job of conducting SCQM. Hence, without the correct understanding of customers' expectation, automakers cannot satisfy customers no matter how much effort they make to manufacturing and controlling components' quality. Furthermore, CXD (CSBSL2, Former Quality Chief) explained the importance of customer-side SCQM from another aspect: *"It's not us but our dealers provide maintenance service to end customers. Their ability in maintenance directly influences end customers' evaluation of our brand's quality"*. This shows that dealers not only collect customer feedback but also provide the objective statistical data of the breakdowns for automakers. It indicates that the cooperation between automakers and dealers is not limited to quality planning but involves product design. In addition, the quality of services that are provided by dealers is treated as automakers' performance in the Chinese market. Hence, dealers' ability directly influences the data quality that is provided to automakers and brand identity.

The interviewees from JVs also claimed that customer-side SCQM contributes the most to their SCQM. During the interview, ZHY (JVSL2, Quality Manager) indicated: *"Instead of merely relying on dealers, we established our electronic business platform 'CBP' last year. To date, we have obtained more than 70,000 pieces of customer information. We could spend much more time and money collecting the same amount of data if we were only cooperating with our dealers"*. It shows that instead of only involving dealers in product design and quality improvement programmes in the past, JVs start to directly communicate with customers by utilising the electronic platforms. This kind of customer-side coordination also assists automakers in designing appropriate new models and establishing appropriate quality goals, which leads automakers to improve operational performance.



**Figure 1: SCQM Framework**

**Table 3: Participated Interviewees and Automakers**

Automaker	Ownership	Interviewee	Duration	Date
JVSL <sub>1</sub>	JV	MZX (Quality Manager)	63mins	12/03/2016
JVSL <sub>2</sub>	JV	ZHY (Quality Manager)	66mins	16/03/2016
CSBSL <sub>2</sub>	CSB	CXD* (Former Quality Chief)	59mins	03/03/2016
CSBO <sub>1</sub>	CSB	SKR (Quality Chief)	48mins	08/03/2016
CSBO <sub>2</sub>	CSB	LBX (Quality Manager)	46mins	18/03/2016
CSBO <sub>3</sub>	CSB	LSZ (Quality Chief)	58mins	04/03/2016

\*: Mr. CXD was promoted to vice-general manager at the interview time.

### The different Customer side SCQM Implementation between CSBs and JVs

Interviewees from CSBs have explained the significant role of dealers from different perspectives. LSZ (CSBO3, Quality Chief) mentioned: *"We set up the annual quality target and plan based on two aspects of information. The first source is the information of after sales that is collected by our 4S dealers. The second source is the market information. It provided by our 4S dealer and the third party's annual quality investigation"*. This demonstrates that CSBs regard dealers not only as the core sources of customer information but also as significant and early contributors to strategic quality planning. However, MZX (JVSL1, Quality Engineer) provided another voice from the perspective of JVs: *"We now rely more on our Market Quality Improvement division to collect customers' feedback. The "800 Hotline", online BBS, and "Technology Hotline", run by our headquarters, also progressively take over the "Survey" and "Service" functions of our dealers"*. Moreover, ZHY (JVSL2, Quality Manager) indicated: *"We also start to work with some websites, such as Taobao and Autohome. They can provide us with more and timely end customers' information based on their big data"*. Those statements show that JVs are trying to contact customers more directly by diverse methods. The original roles of JVs' dealers, such as investigating customers' user experience, are being diluted. These dealers start to concentrate on test driving, vehicle delivery, and other functions. In the Chinese automobile market, JVs control and own more and better resources than CSBs (Lu et al., 2014). Hence, JVs are more capable of implementing advanced digital technology to collect customer information and provide better service. Furthermore, McKinsey (2015) clarified that the development of digital technology could help automobile manufacturers to gather more real-time customer information that can lower development costs and speed up the time to market by big data simulations and virtual modelling.

Overall, the case study verified the important role of customer side SCQM in automakers. However, CSBs mainly rely on dealers to identify customer requirement and involve dealers to its model design and continuous improvement as early as possible. On the other hand, JVs focus on its own department to collect customer feedback by more direct and diverse channels, such as electronic platforms and mobile applications.

### CONCLUSION

The survey study addressed the first research question. We found that customer side SCQM is the most influential factor in improving operational performance in the Chinese automobile market. The second research question was answered by the follow-up case study. We summarized that both CSB and JV treat customer side SCQM as the indispensable factor in continuous improvement. We also distinguished their different practices of customer side SCQM implementation. The findings of this paper assist in gaining a deeper understanding of the key relationships between SCQM practices and performance by illustrating that customer side SCQM has the most significant impact on operational performance. Moreover, the comparison between CSB and JV expands the SCQM theory by clarifying the different customer side SCQM practice in the network environment. Further, our study answers the calls for ownership and emerging market research in SCQM launched by Foster (2008), and Huo et al. (2014). In terms of managerial implications, this paper enhances the understanding of quality and supply chain managers about the best SCQM practices. With the development of information technology and the change of customer's consumption habit, automakers should start to adjust their customer side SCQM by shortening the distance to customers and applying more digitalized

cooperation practices. It is important to evaluate the results and contributions of our research with limitation. Due to the limited time and access, we only compare CSBs and JVs. Although they had different ownership, future research should include more IBs to enhance the generalization of our findings.

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# RELATIONSHIP BETWEEN BUYER AND SUPPLIER IN OUTSOURCING OF INFORMATION TECHNOLOGY SERVICES

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## ABSTRACT

Companies rely on others to achieve its goals. This is not only true in terms of management of the flows of information and materials through the supply chain but also in terms of performing specific processes and sub-processes intimately related to the company's operation. IT Outsourcing (ITO) is increasing worldwide and the relational governance impacts the outsourcing outcomes (Lacity et al, 2016). This perspective is usually visited for the buyer and supplier perspectives using decision makers and leaving a gap in literature in terms of the perspective of the consultants.

This paper aims at analysing, in ITO, how the development of the relationship between buyer and supplier strengthens supplier performance over time, from the perspective of the consultants. A survey to IT consultants was applied and then a multilevel analysis was performed, taking account for the aggregate values of the variables characterizing buyer supplier relationships based on Johnston and Staughton (2009), Krause et al. (2007) and Blonska et al. (2013).

Findings show that strategic relationships are associated with higher supplier investment in relational management. In this type of relationship higher levels of trust are linked to an attribution of more recognised benefits from the relationship, and reciprocal investment to the buyer. Furthermore, an improvement of the dedication in the relation and an improved service performance were attributed by IT consultants to the supplier.

Keywords: IT outsourcing; buyer supplier relationship type; relational governance; relational management; supplier development; B2B relations

## INTRODUCTION

The IT Outsourcing (ITO) business in 2015 was up to 157 billions of dollars worldwide (Marorelli and Benkel, 2015), a number that highlights the relevance of this type of outsourcing to companies and, consequently, for supply chain performance. Managing ITO contracts involves two sides: the hard and the soft ones (Barthélemy, 2003). The hard side relates to the development and execution of a rigid contract. The definition of the contract has impact on the quality of the IT service provided as it can reduce ambiguity in the output, while the soft side relies on the development of relational management, increasing trust between the partners, contributing to higher mutual obligations and enhanced outcomes (meta-analysis presented) (systematic reviews presented by Lacity et al., 2016, and by Liang et al, 2016). However, is not clear in which circumstances investment in relational management could produce higher outcomes. In this paper it is sustained that, from a supplier-buyer perspective, relational management has higher impact on strategic relations where the quality of interaction will greatly affect IT consultants performance, and lead to a generic performance improvement on both parties involved (Krause et al., 2007), than on

transactional relationships where both parties might concentrate on the strict fulfilment of the contracts.

Relations between companies are paramount to supply chain performance as it involves the access to resources or competences and impacts outcomes and the value proposition of the buying company (Ford et al., 2003). The established relationships can be more strategic or more tactical (Johnston and Staughton, 2009), which will impact the quality of the services the buyer companies provide and their competitive positioning in the supply chain (Johnston et al., 2012). Transactional relationships are often characterised as "arm's length" relationships (Henderson, 1990). These are often short term relationships (but can also last for long periods) in which the buyer can easily replace the supplier without harm to its regular business. Strategic relationships, on the other hand, involve inter-dependency from both parties toward a common goal. As so, these are usually long term relationships with sharing of risks and benefits between the parties. Accordingly, it is expected that strategic relationships contribute more to suppliers' development by making investments in their ability to provide the outsourced service (either by supporting managerial development, by providing financial support or by transferring human resources), assuring higher service quality and strengthening future mutual relationships.

Usually the assessment of the performance of the relationship between buyer and supplier is based on inputs from the participating companies. Nonetheless, the relational management in ITO is put to practice, in great extent, by the consultants and strongly influenced by the collaboration of the buying company. In this vein, this paper aims at analysing, in ITO, how the development of the relationship between buyer and supplier strengthens supplier performance over time, from the perspective of the consultants. This perspective might allow understand how the vivid experience of the actors on the field affects and is affected by the relational management and the soft side of ITO relationships, generically.

In order to achieve its goal this article grounds its literature review on the types of relationship between parties as well as suppliers' development. The survey results from the collection of several variables, adapted to the IT area. Data was collected from consultants working in different pairs of supplier-buyer relationships and after aggregated at the organizational level, which allowed testing the proposed hypotheses.

## **THEORETICAL BACKGROUND AND HYPOTHESES**

### **Types of relationship and relationship development**

Business-to-business (B2B) relationships can be of different nature. These are influenced by the persons involved, therefore can change as the persons involved also change (Johnston et al., 2012). Particularly, strategic relationships require interaction (Johnston and Staughton, 2009), collaboration and trust between the parties involved, contributing to the believe that they can link their own value chains to the benefit of the relationship (Johnson et al., 2012). Although formal contracts may exist, it is the spirit of the relationship that shapes how the parties interact (Johnston and Staughton, 2009). At the level of consultants, complying with contracts and mostly evidencing behaviours beyond what is strictly expected (like organizational citizenship behaviours), as well as interaction between remaining workers and departments can lead to better working conditions and improved individual and organizational performance (Andrews, 2011). Furthermore, information sharing leads to increased competitive edge, data concerning the needs of the buyer, changes in the market as well as competitors should flow between the parties (Hult et al., 2000). It can be concluded that both organizational citizenship and information sharing are relevant issues in the relationship, being this way interrelated. Based on the provided context, the following hypothesis is formulated:

*H1: Information sharing between the buyer and the supplier is positively linked to organizational citizenship between the workers of the buying company and the consultants from the supplier.*

Trust is a relevant issue for the development and success of the relationship. It consists of the degree in which one of the parties recognises competence in the other to perform the requested activities (Ganesan, 1994). Trust is also considered a facilitator of the relational capital (Faraj and Wasko, 2005) contributing to the robustness of the personal relations developed during the interactions between the parties involved in the relationship (Nahapiet and Ghoshal, 1998). Strategic relationships have a higher number of activities in the relation, being a cause and effect of trust. On one hand higher levels of trust will lead to increase the quality of future interactions, depending on informal work relations (Whipple et al., 2010). On other hand, trust between parties depends on reciprocity throughout time. Consequently, levels of trust will develop according to the intensity of interactions (activities in the relationship), which are expected to be higher in strategic relationships. Consequently, the following hypotheses are formulated:

*H2: The more strategic the relationship is the more positive is the association with perceived trust between parties.*

*H3: The higher the activities in the relationship the higher the level of perceived trust between parties.*

Guidance toward a long term compromise by the buyer is the perception and expectation that these have on the benefits it will receive from the supplier. Partners with a short term perspective are more concerned with short range results but when there is a long term perspective partners are concerned with both short and long term results (Ganesan, 1994). According to the same author, the range of the compromise also influences the nature of the exchange between the workers from the different companies: long term relationships depend on the exchanges between parties to maximize the outcomes. Long term relationships also reduce buyers' risk and enforces trust that short term concerns will be overcome (Ganesan, 1994). As so, the following hypothesis is formulated:

*H4: Long term compromise between buyer and supplier is positively related to the perceived trust between them.*

### **Supplier development and dedication investments**

Supplier development practices are activities performed by the buyer to improve the supplier's performance or skills (Krause et al., 1998), allowing higher cooperation between the two parties, developing technical knowledge, promoting quality, distribution and ability to manage the supplier's costs. Also, dedication investments are investments made either by the buyer or the supplier in a relationship (Heide and George, 1990), that contribute to the dependency between the parties and show signs of compromise. In this vein, Wagner (2006) defined six dimensions for supplier development: four indirect (Ad hoc, Formality Level, Assessment and Communication) and two direct ones (Human and Capital). Wagner (2006) refers that some technological industries have already enrolled in these practice and concludes that they contribute to organizational success. However, supplier development has its risks as the buyer might be investing in knowledge and skills that can be used by the supplier to reinforce its competitors, but the expectation is that the investment is used on its own company (Blonska et al., 2008). The same author argues that the shift from a more transactional to a more strategic relationship leads the buyer to invest in supplier development. Based on the previous arguments, the following hypotheses are developed:

*H5: The more strategic the type of relationship is the more positive will the association with supplier development practices be.*

*H6: Supplier development practices by the buyer are positively associated with dedication investments towards the supplier.*

### **Knowledge transfer between buyer and supplier**

Knowledge transfer consists on how the knowledge shared by one party is received and applied by the other (Ko et al., 2005). This transfer is reported frequently in ITO focused on the degree in which the buying companies absorb and use the knowledge from its suppliers (Park et al., 2011). This transfer is dependent on the ability of the sender to code and share its knowledge as well as the receiver to value, assimilate and use this new knowledge (Cohen and Levinthal, 1990). This transfer is only possible if there is continuity in the relationship and an intense contact between the two parties (Kale et al., 2000). Long term relationships lead the knowledge sender to be more predispose to invest time to assure that knowledge transfer is successful (Uzzi, 1997). In the ITO market, trust and cooperative learning between buyer and supplier are necessary to allow the buyer to capture knowledge from its supplier (Park et al., 2011). As so, and according to the same authors, the IT consultants working directly at the buyer's facilities should develop a cooperation relation with the buyers so that these can absorb the most knowledge out of the outsourcing relationship. As this transfer is based on the Human dimension of supplier development, the following hypothesis is presented:

*H7: Supplier development practices using the Human dimension by the buyer is positively associated with information sharing between the buyer and the supplier.*

### **Supplier performance**

Stank et al. (2003) proposed a 3 dimension construct to assess supplier development: operational, costs, and relational performance. This is a model focussed on the logistics area. In this area, the benefits shared during the relation are defined as a performance improvement that the outsourcing relationships allow the buying company and that should be assessed. Knemeyer et al. (2003) provide examples of potential improvement issues in the logistics area. Thus, it can be expected that in ITO strategic relations will enhance supplier performance leading to the following hypothesis:

*H8: The more strategic is the relationship between buyer and supplier the stronger is the positive association with the benefits from the relation measured using supplier performance metrics.*

## **METHODOLOGY**

### **Research instrument and data collection**

In order to collect data that would allow testing the hypotheses a questionnaire based on Johnston and Staughton (2009), Krause et al. (2007) and Blonska et al. (2013) is used with adaptation to the IT area. This questionnaire has four groups of questions and questions to assess respondents' eligibility (eg. required to stay at the buyer's company at least 20 hours per week). The first group comprises items concerning information sharing and assessment of relationship performance. The second part contains the items to assess the relationship between the consultant and the buyer. The third part relates to the characterization of the consultant and its professional situation in both the buyer and the service supply company (supplier). The fourth part aims at assessing long term relationship and dedication investments. A Likert like scale was used in the questionnaire ranging from 1 – "Strongly disagree" to 7 – "Strongly agree". A "do not know" option was always available to prevent respondents from providing answers when they did not know about the item.

The questionnaire was pre-tested with 10 consultants from different service suppliers working at buyers' companies. Consequently semantic adjustments were introduced and the length of the questionnaire was reduced to increase the number of responses. Data was collected using Survey Monkey during May and June 2016. Questionnaires were individually sent by email and also made available at LinkedIn.

### **Sample**

Out of 260 valid responses it was possible to identify 89 different pairs of supplier-buyer relationships, which result in 142 full responses from consultants. The

aggregation of the pairs was only possible as the consultants identified the name of the companies involved (confidential disclosure was assured).

Four variables were considered to characterize the sample of the 89 pairs. Respondents (consultants) work mainly at a single buyer project (79,8% work 40 to 50 hours per week at the same buyer) and 29,2% of the consultants are at the same buyer project for at least two years. Out of the 89 pairs of supplier-buyer relations, 42% of the buyers are from the telecommunication sector, 25% from general services and 20,5 % from banking and insurance.

In this first group their opinion about the type of relationship was also asked (detailed meaning was presented): transactional (22,7%); transactional but with some characteristics of strategic (25%); strategic but with some characteristics of transactional (31,8%); strategic (20,5%).

## ANALYSIS OF VARIABLES

In order to test the hypotheses the variables were built based on the items from the original studies. Exploratory factorial analysis was performed and the principal component method was used with Varimax rotation. Suitability was assessed using Kaiser-Meyer-Olkin (KMO), and through the analysis of the internal consistency (Cronbach Alpha).

All of the original 5 items from *Activities in the relationship* were considered and excellent consistency was found ( $\alpha=0,909$ ). Globally, this scale showed good homogeneity (KMO index = 0,890).

*Long term compromise* was operationalised using 4 of the original variable items. Good internal consistency was found ( $\alpha=0,898$ ) as well as good homogeneity (KMO index = 0,819).

In terms of *Trust*, all 6 original items were considered. Excellent internal consistency was found ( $\alpha=0,919$ ) for the scale as well as good homogeneity (KMO index = 0,889).

*Dedication investments* was considered with all its 3 items. Good internal consistency was obtained ( $\alpha=0,872$ ) as well as average homogeneity (KMO index = 0,740).

For *Information sharing*, the 3 original items were considered. Good internal consistency was achieved ( $\alpha=0,873$ ) for the scale as well as average homogeneity (KMO index = 0,713).

*Supplier development* was analysed based solely on the *Human*, *Capital* and *Formal* dimensions as it was considered that the consultants would not have information to assess the remaining 3 dimensions. For *Human* only 4 out of the original 5 items were used and good internal consistency was found ( $\alpha=0,899$ ). For *Capital* the 2 original items were used and reasonable internal consistency was found ( $\alpha=0,792$ ). For *Formal* all 4 original items were used and excellent internal consistency was obtained ( $\alpha=0,941$ ). Globally, this scale showed good homogeneity (KMO index = 0,891).

In order to analyse *Organizational citizenship* all 7 items from the original research were considered. The scale showed excellent internal consistency ( $\alpha=0,936$ ) and good homogeneity (KMO index = 0,893).

*Supplier Performance*, was assessed through 8 items, presenting good internal consistency ( $\alpha=0,938$ ) as well as good homogeneity (KMO index = 0,888).

## HYPOTHESES TESTING

Correlation matrixes and linear regression models were used to test the hypotheses.

To test H1 Pearson correlation was used. *Information sharing* showed a significant correlation with *Organizational citizenship* ( $r=0,471$ ,  $p<0,01$ ). Therefore, H1 is not rejected.

As for H2, Pearson correlation showed that *Trust* is positively correlated to *Type of relationship* ( $r=0,447$ ,  $p<0,01$ ). It is then possible to conclude that the relationship is recognised as more strategic as the consultants perceive more trust in the relationship between the buyer and the supplier. As so, H2 is not rejected.

H3 was also tested using Pearson correlation. It was found that *Activities in the relationship* is moderately correlated to *Trust* ( $r=0,429$ ,  $p<0,01$ ). These results show

that as there are more activities in the relation between buyer and supplier, the consultants recognise more trust. As a consequence, H3 is not rejected.

When testing H4 Pearson correlation showed that *Long term compromise* is positively and significantly correlated with *Trust* ( $r=0,483$ ,  $p<0,01$ ), which allows concluding that trust tends to exist in long term relationships. This way H4 is not rejected.

In order to analyse H5, 3 Linear Regression Models were conducted, each with independent variable the corresponding component of *Supplier Development* (*Human*, *Capital* and *Formal*). The independent variable used was *Type of Relationship*. Concerning the first model, the introduction of the independent variable allowed increasing the power of explanation of the model to 10,2% ( $R^2=0,102$ ;  $\Delta R^2=0,08$ ;  $p=0,006$ ). Analysing variance using ANOVA,  $p=0,029$ . Type of relationship showed  $p=0,006$ , which allows concluding that the more strategic the relationship is the more supplier development exists based on the human component. In terms of dependent variable supplier development – capital, the introduction of Type of relationship in the model increased the explanation power of the model to 18% ( $R^2=0,180$ ;  $\Delta R^2=0,112$ ;  $p=0,001$ ). A more detailed analysis showed  $p=0,001$ , which allows concluding that the more strategic the relationship is the more there is supplier development using the capital dimension ( $\beta=0,351$ ;  $p<0,01$ ) and that the less contact the consultant has with the buyer, the more supplier development exists in terms of financial support. Lastly, using supplier development – formal as dependent variable, the introduction of Type of relationship as independent variable allowed increasing the power of explanation of the model to 22% ( $R^2=0,022$ ;  $\Delta R^2=0,064$ ;  $p=0,015$ ), nonetheless, the Anova test showed that the relationship is not significant ( $p=0,276$ ). Based on all the analysis performed, it is possible to conclude that H5 should not be rejected.

The analysis of H6 also involved 3 Linear Regression Models. The dependent variables were, respectively, *Supplier Development Human*, *Capital* and *Formal*. Using as independent variables *Trust*, *Dedication Investment* and *Long Term Compromise*, and *Human* as dependent variable, it was found that *Dedication Investments* is the variable influencing *Supplier Development Human* ( $p=0,001$ ), i.e., the more dedication investments there is by the supplier company the more supplier development exists from the dimensions transferred by the buyer. When analysing dimension *Capital*, using the same independent variables ( $R^2=0,107$ ;  $p=0,022$ ), it was found that the investment in supplier development using the *Capital* component is higher when there are more labour hours by the consultant at the supplier's company and lower when the consultant spends more time at the buyer company ( $\beta=0,395$ ;  $p<0,05$ ). When *Dedication Investments* was introduced to the model it increased its explanation power to 28,9% ( $R^2=0,289$ ;  $\Delta R^2=0,182$ ;  $p=0,000$ ). ANOVA test showed that one of the variables was influencing the *Capital*. It was found that *Dedication Investments* have a larger influence, i.e., the more there is supplier development from investment, the more dedication investments are between the parties ( $\beta=0,475$ ;  $p<0,05$ ) as the two variables are directly related. Lastly, *Supplier Development* from its *Formal* component was used as dependent variable and *Dedication Investments* as the independent one. The model showed a good significance level ( $R^2=0,174$ ;  $\Delta R^2=0,206$ ;  $p=0,000$ ) highlighting that the dedications investments made by the supplier contribute positively to supplier development in the formal component (assessment) ( $\beta=0,500$ ;  $p<0,05$ ). Based on the three analyses, H6 is not rejected.

As for H7, Pearson correlation showed that *Supplier development* in the component *Human* has a good and positive correlation to *Information sharing* ( $r=0,606$ ,  $p<0,01$ ), which allows concluding that transferring resources and knowledge for supplier development is positively linked to information sharing between buyer and supplier. As a consequence, H7 is not rejected.

Testing H8 involved a Linear Regression in which *Supplier performance* was the dependent variable. Including *Type of relationship* as independent variable allowed improving the quality of the model ( $R^2=0,143$ ;  $\Delta R^2=0,144$ ;  $p=0,000$ ). A more detailed analysis allowed concluding that the more of a strategic type the relationships are the more benefits exist from the relationship which are measured using Supplier's performance assessment ( $\beta=0,395$ ;  $p<0,05$ ). This way H8 is not rejected.

## DISCUSSION

Findings showed that *Information Sharing* is positively linked with both *Organizational Citizenship* and *Supplier Development* practices. The correlation matrix also showed a significant correlation between *Information Sharing* and the *Type of Relationship* (of strategic nature). It was also possible to conclude that *Trust* is positively related to the *Type of Relationship* (of strategic nature), to *Activities in the Relationship* and *Long Term Compromise* between buyer and supplier. This shows that *Information Sharing* and *Trust* are recognised by the consultants as related to practices of bonding in the supply chain. These findings are in line with supply chain management literature.

Findings showed that the more strategic the relationships between buyer and supplier, the more the consultants recognise that there are Supplier development practices, both from human and financial perspectives (Krause et al., 2007; Johnston and Staughton, 2009). Strategic relationships are typically long terms ones, with sharing of goals and continuous interaction, therefore consultants recognise that the investment in development practices are stronger.

It was also found that the more strategic the relationship is, usually associated to *Long Term Compromises*, the more it is recognised by the consultants to be linked to more benefits to the buyer. This is in line with the literature review (Ganesan, 1994) as long term relationships, and the stability that it brings to the supply chain, leads to competitive advantages to the companies involved. It was found that the consultants perceive strategic relationships as more beneficial to the buyer and that, consequently, those benefits reflect in their activities.

Correlations showed that consultants perceive strategic relationships as positively linked to long term compromises, which leads to more dedication investments that are recognised by the consultants. Finally, consultants recognise that investments in dedications, namely in human development and equipment are linked to the type of relationship between the parties.

## CONCLUSIONS

This research aimed at analysing if there are supplier development practices in IT outsourcing, which are recognised by the consultants. Eight hypotheses were developed, based on literature.

Findings lead to not reject any of the hypotheses. It was found that strategic relationships are associated with greater supplier investment in the relationship. In this type of relationship higher levels of trust are linked to an attribution of more recognised benefits from the relationship, and reciprocal investment to the buyer. Furthermore, an improvement of the dedication in the relation and an improved service performance was attributed by IT consultants to the supplier. It was also shown that there is a link between the sharing of information from both parties and the results of the service supplied. These findings are in line with those from Krause et al. (2007), Johnston and Staughton (2009) and Ganesan (1994), but the perspective from the consultants is new.

Findings are limited to the sample used as it is a convenience one. Nonetheless the data collection instrument proved to be reliable and able to be used in similar analysis. Further research to expand the sample used and to assess if cultural issues, such as those derived from nationality, could be assessed. Furthermore the use of external informants like representatives of supplier and buyer companies will contribute to reduce common method variance bias.

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# THE IMPACT OF POWER ON RELATIONSHIP AND CUSTOMER SATISFACTION IN LOGISTICS TRIAD: A META-ANALYSIS

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## **Abstract**

**Aim/Purpose:** It is necessary for TPL firms to understand power source and relationship between buyers and suppliers so that they can improve logistics performance and customer satisfaction. This paper uses a meta-analysis to assess the effect of power on relationship and customer satisfaction in a logistics triadic relationship.

**Design/methodology/approach:** A meta-analysis is useful to systemically synthesize the research findings from the existing literature. The causal relationships between power, relationship and customer satisfaction is statistically assessed from the SCM and logistics literature.

**Findings:** Based on the review and analysis, the framework may provide significant implication for supply chain relationship in Logistics.

**Value:** This may be the first attempt to analyse the impact of power on relationship and customer satisfaction in logistics triad through a meta-analysis. The results of this study will be useful research information that other researchers can use.

**Practical implications:** Previous studies have explored the causal relationship between logistics services and customer satisfaction in a dyadic perspective. This study aims to extend the focus on the power and the relationship in the supply chain to the triad perspective. This may contribute to the literature by presenting theoretical bases and models for studying logistics services from the triadic relationships which is common practice in the industry.

**Keywords:** logistics triad, power, relationship, logistics service performance, Meta-analysis

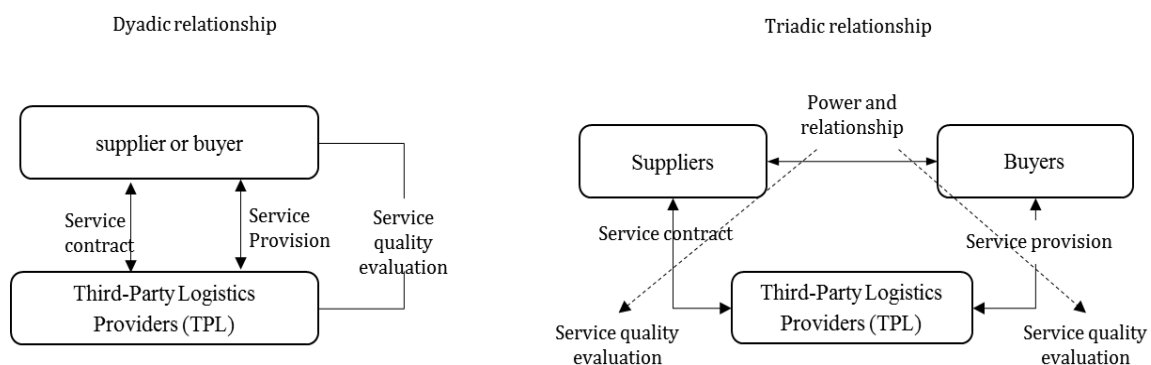
## **Paper Category: Research paper**

## **1. INTRODUCTION**

Multinational production network systems have been established as a strategy to secure and maintain corporate competitive advantages to respond to increased global market competition, diversified consumer demand and continued uncertainty. In addition it has become the norm for manufacturing companies to focus on their core business and outsource other functions. These changes increase dependence on companies in supply chains and recognition on importance of managing supply chains effectively (Woo et al., 2013). Relations among firms in a supply chain forms an important dimension in understanding a supply chain since the essential characteristics of the supply chain can be its organizational relationships (Skjott et al., 2007). Various forms of relationships can emerge in the supply chain ranging from traditional arm's-length relationships to strategic partnership (Ellram and Cooper, 1990). Strategic partnership has been suggested for effective supply chain management recognizing interdependence among supply chain partners whereas traditional arm's-length relationship limit long-term relationship in the supply chain (Ellram and Cooper, 1990). It is suggested that power source has influence on relationship development in the supply chain (Benton and Maloni, 2005). Therefore the impact of power source on relationship development in the supply chain has been well studied (Maloni and Benton, 2000; Benton and Maloni, 2005).

When logistics service is outsourced to third-party logistics (TPL) firms, logistics services are provided to meet demand of logistical functions within or between firms in supply chains. An argument is that logistics services should be variably provided depending on relationship with customers (Bask, 2001). While standardized general services have advantages for moderate relationship, customized TPL services are suggested for in the close partnership settings (Makelin and Vepsalainen, 1990; Bask, 2001). However, the existing literature is in the contextual settings of dyadic relationship which considers relationship between either supplier and TPL provider or buyer and TPL, whereas it is suggested that the minimum unit of analysis in TPL studies should be the logistics triad which consider buyer, supplier and TPL firms (Sohn et al., 2017). In the logistics triad, relationships not only between supplier or buyer and TPL firms but also between supplier and buyer are considered as shown in Figure 1. Therefore the relationship between supplier and buyer is concerned in the discussion of matching logistics services and customer relationships in the logistics triadic setting. From the TPL firms' perspective, it is important to understand the causal relationships between power and relationship and customer satisfaction so that they can develop logistics services appropriate for supply chains with different types of relationships.

Figure 1. Relationships in a logistics triad



Meta-analysis is a useful quantitative approach to synthesize the result of a series of studies (Brockwell and Gordon, 2000; Orlitzky et al., 2003). The method focuses on the effect size of causal links by combining the estimates of effect size from each study to obtain the average effect size across studies (Glass, 1976). This approach is also related with generalizability of research findings by examining the relationship of variations in research outcomes. There have been studies on the examination of the impact of power source on relationship development and performance in the supply chain. Reviewing and synthesizing the causal relationship by combining the effect size of such studies is essential to assess the generalizability of the findings with confidence. On the other hand it is also important to investigate the influence of the study characteristics on the research outcome for example studies in different industry, countries and research time (Hunter and Schmidt, 2000). Therefore this study conducts meta-analysis on the existing studies that empirically examined the causal relationships. To this end, the relevant studies in the supply chain literature are identified through search in the research databases and the information necessary for meta-analysis is collected. The result of the meta-analysis will be the theoretical foundation for setting the research model in follow-up researchers and serve as a useful research information for other researchers.

## 2. THEORETICAL BACKGROUND AND RESEARCH FRAMEWORK

### 2.1. Power concepts and causal link

Understanding supply chain relationship from the perspective of 'power regime' has been well studied in the early 2000s (Cox, 1999; Cox, 2001; Cox et al., 2001). These studies provides conceptual framework suggesting that power regimes perspective should be adopted because values are variably allocated in the extended dyadic exchange networks which is supply chain depending on properties of power in the networks (Cox et al., 2001).

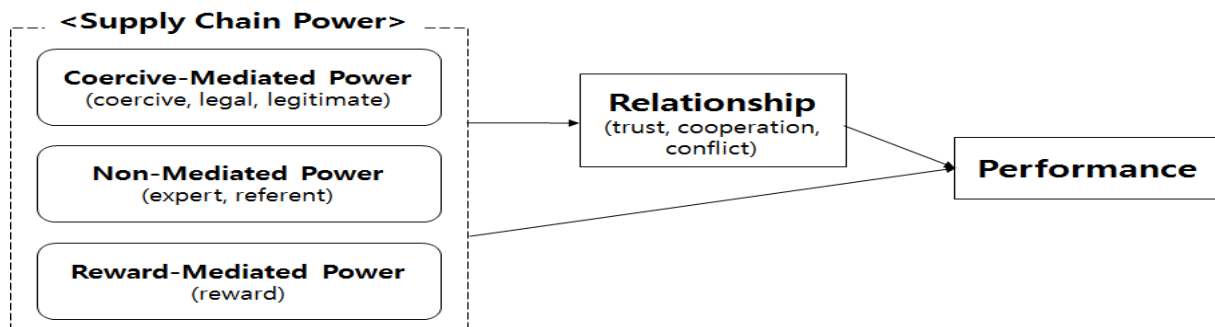
Based on the analytical framework, various case studies are conducted in multiple-industries (Cox et al., 2004), fashion industry (Hines and McGowan, 2005), food industry (Hingley, 2005a; 2005b; 2005c; Kähkönen, 2014) and smartphone industry (Chen and Wang, 2015). These studies generally explore origins and features of power and influence of power on the supply chain practices such as integration and collaboration (Kähkönen, 2014; Meehan and and Wright, 2011; 2012).

Accordingly empirical examination of the impact of power on relationship development and performance has drawn attention from SCM researchers (Maloni and Benton, 2000; Benton and Maloni, 2005). The literature classified the type of power into five depending on power sources as shown in Table 1 (Weiling et al., 2009; Chang, 2009). It is suggested that the relationship between the companies in supply chains stems from a disparity of power and partner companies' ability (Hart and Saunders, 1998). The relationship can be developed in the form of trust, cooperation and conflict and the relationship has influence on firm and supply chain performance as shown in Figure 2. There has been an increasing number of empirical studies examining the causal relationships as shown in Table 2.

Table 1. Definition of Power

Classification	Power Base	Definition
Mediated	Reward	<p>"Reward power depends on the ability of the power holder to administer positive valences and to remove or decrease negative valence" (French &amp; Raven, 1959: 156).</p> <p>"Source retains ability to mediate rewards to target" (Maloni &amp; Benton, 2000).</p>
	Coercive	<p>"Coercive power stems from the expectation on the part of the power recipient that he will be punished by the power holder if he fails to conform to the influence attempt" (French &amp; Raven, 1959: 157).</p> <p>"Source holds ability to mediate punishment to target" (Maloni &amp; Benton, 2000).</p>
	Legitimate	<p>"Target values identification with source" (Maloni &amp; Benton, 2000).</p> <p>"Legitimate power is defined as that power which stems from internalized values in the power recipient which dictate that the power holder has a legitimate right to influence the power recipient and that the power recipient has an obligation to accept this influence" (French &amp; Raven, 1959: 159).</p> <p>"Target believes source retains natural right to influence" (Maloni &amp; Benton, 2000).</p>
Non-mediated	Expert	<p>"The strength of expert power varies with the extent of the knowledge or perception which the power recipient attributes to the power holder within a given area" (French &amp; Raven, 1959: 163).</p> <p>"Source has access to knowledge and skills desired by target" " (Maloni &amp; Benton, 2000).</p>
	Referent	<p>"Referent power has its basis in the identification of the power recipient with the power holder" (French &amp; Raven, 1959: 161).</p>

Figure 2. Research framework



## 2.2. Meta-analysis literature in SCM research

There have been review papers in SCM research for the last two decades (e.g. Skjoett-Larsen, 1999; Chen and Paulraj, 2004; Sachan and Datta, 2005; Burgess et al., 2006; Ballou, 2007; Srivastava, 2007; Seuring and Gold, 2012; Carter and Liane Easton, 2011). These studies review research themes, approaches and methodologies used in the SCM literature and suggest generally future research agenda (e.g. Skjoett-Larsen, 1999; Chen and Paulraj, 2004; Ballou, 2007). Some studies used more systemic review approach by categorising the sample literature by research philosophy, topics, methods etc. (e.g. Sachan and Datta, 2005; Burgess et al., 2006). Srivastava (2007) and Carter and Liane Easton (2011) focus on particular research areas such a green and sustainable supply chain management. Furthermore some review studies address a methodological issues such as validity assessment and its criteria in structural equation modelling (Kaynak and Hartley, 2008) and common method variance in survey studies (Craighead et al., 2011).

On the other hand, Goldsby and Autry (2011) suggest that meta-analytic techniques should be used in SCM research so that research findings can be synthesized and applied by researchers and practitioners with more confidence. Meta-analysis has been used in various research area where research findings from the individual studies have inconsistency or conflicts (Damanpour 1991; Datta et al. 1992; Hunter and Schmidt, 1990). Subsequently meta-analyses are conducted in SCM research: sustainable SCM and firm performance (Golobic and Smith, 2013), inter-organisational trust and supply chain relationships (Delbufalo, 2012) and supply chain integration and firm performance (Leuschner et al., 2013). With the increase of the empirical examination of power-relationship-performance links, it is worthwhile to synthesize the research findings from the literature.

## 3. RESEARCH METHODOLOGY

In this section, we first describe sample selection and the coding of the studies is explained. Then, we detail the meta-analytic procedures that were used to test the hypotheses.

### 3.1 Sample selection

To collect the existing studies in power and relationship in the supply chain research, this study searched through google scholar, Emerald Management Xtra(EMX), Wiley Online Library(WOL), JSTOR. We used keywords such as supply chain, power, logistics, relationship, performance and identified 41 papers. Subsequently the studies that do not include empirical hypotheses testing were excluded and finally the studies that used power as independent variables in the causation remained in the dataset as shown in Figure 3. The earliest paper was published in 1995 and the latest was 2017.

Figure 3. Review process for supply chain power

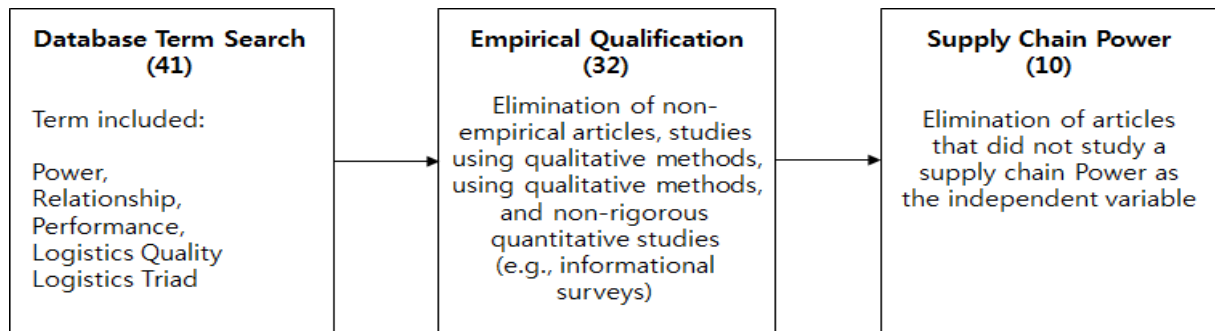


Table 2. Summary of Study Data

Authors	Independent Variable	Dependent Variable	n	No. of r's
Benton and Maloni (2005)	coercive-mediated non-mediated reward-mediated	relationship	180	3
Chae et al. (2017)	coercive-mediated non-mediated reward-mediated	relationship	1229	5
Rawwas et al. (1997)	coercive-mediated non-mediated reward-mediated	relationship	551	5
Zhuang et al. (2010)	coercive-mediated non-mediated	relationship	225	4
Ke et al. (2009)	coercive-mediated non-mediated reward-mediated	relationship	134	10
Terpend and Ashenbaum (2012)	coercive-mediated non-mediated reward-mediated	relationship	225	5
Nyaga et al. (2013)	coercive-mediated non-mediated reward-mediated	relationship performance	242	15
Pulles et al. (2014)	coercive-mediated reward-mediated	relationship	185	4
Brown et al. (1995)	coercive-mediated non-mediated reward-mediated	relationship performance	203	20
Bandara et al. (2017)	coercive-mediated non-mediated	relationship performance	284	4

### 3.2 Effect size evaluation

The formula for the estimating the effect size of causal links are presented in this section. In this study, correlation effect size between power, relationship and performance was used to calculate the effect size. The correlation effect size was calculated using Fisher's Z transformation because Fisher's Z follows normal distribution (Lipsey and Wilson, 2003). The formula for converting Simple correlation coefficient into Fisher's z set as follows:

$$Z = .5 \times \log\left(\frac{1+r}{1-r}\right)$$

where, r is simple correlation coefficient.

The formula for calculating the variance of z is as follows:

$$V = \frac{1}{n-3}$$

Where, n is sample number of used in the study.

The standard error of the measured effect size can be obtained by the square root of the variance as below:

$$SE_z = \sqrt{V_z}$$

#### 4. RESULTS OF ANALYSIS

The literature search uncovered 10 studies that examined the correlations between power type, relationship and performance. The ten studies reported total 75 separate correlations. R version 3.3.2 (2016-10-31) statistical software was used to analyse the Fisher's Z transformed correlation effect size. A homogeneity test was performed to determine whether the studies were homogenous testing the effects of the full data. The effect size of research disposition were heterogeneous with  $Q=3054.86$  ( $p<0.001$ ). Therefore, the overall effect size was measured using the random effects model. Effect sizes were also compared by the characteristics of each study.

Table 3. Homogeneity of Meta-analysis results

K	Q	p-value	-95%CI	ES	+95%CI	SE
75	3054.86	<.0001	0.177	0.190	0.203	0.118

Note: k=number of effect size; Q=homogeneity statistics; p-value: the alpha to homogeneity statistics value; 95%CI: 95% Confidence Interval; ES=effect size; SE=standard error.

According to Cooper (2010),  $ES=0.1$  is defined as a small effect in personality, social and clinical psychology research, and  $ES=0.5$  is a large effect in sociology, economics, and experimental or physiological psychology and  $ES=0.3$  as medium effect. Therefore this study presents a small effect size in correlational meta-analysis (Ellis, 2010). All meta-analysis results are summarized in Table 4. Looking at the effect size by power type, the effect size of non-mediated power (0.424) is greater than coercive-mediated power (-0.083), reward-mediated Power (-0.0005). It was shown that non-mediated power (expert and referent) has a higher relationship with relationships than coercive-mediated power (coercive, legal and legitimate) and reward-mediated power.

Table 4. Summary of Meta-analysis results

Random effect model							
K	Q	p-value	-95%CI	ES	+95%CI	SE	
75	3054.86	<.0031	.043	.129	.214	.118	

Key constructs	K	Q	p-value	-95%CI	ES	+95%CI	SE
Non-mediated power	29	470.42	.0001	.336	.424	0.512	.196
Coercive-mediated power	31	893.03	.0001	-.198	-.083	.031	.189
Reward-mediated power	15	334.44	.0001	-.152	-.0005	.151	.289

Note: k=number of effect size; Q=homogeneity statistics; p-value: the alpha to homogeneity statistics value; 95%CI: 95% Confidence Interval; ES=effect size; SE=standard error.

#### 5. CONCLUSIONS

With the empirical analysis testing SCM theories increasing recently, meta-analytic approach is being adopted in SCM research more than before. Meta-analysis was conducted on the power-relationship links in this study to synthesize and generalize the findings from the empirical analysis on the examination. Homogeneity test using all the correlation coefficients showed that the sample studies were heterogeneous. Therefore, this study used the random effect model to calculate the size of the correlation coefficient effects according to the types of power. The results are that non-mediated power has a higher contribution to relationship development than coercive-mediated power and reward-mediated power do. Contribution to the literature is that this study combined the research findings from the relevant literature. However the relatively small number of sample papers included in this study is inevitable limitation.

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## APPENDIX A. List of Samples and Articles (Supply Chain Power)

Sample	No	Authors	Year	Journal	Sample size
1	1	Benton, W. C. and Maloni, M.	2005	JOM	180
2	2	Chae, S., Choi, T. Y. and Hur, D.	2017	JSCM	1229
	3	Huo, B., Flynn, B. B. and Zhao, X.	2017	JSCM	
	4	Maloni, M. and Benton, W. C.	2000	JBL	
3	5	Rawwas, M. Y. ., Vitell, S. J. and Barnes, J. H.	1997	JBR	551
	6	Yeung, J. H. Y., Selen, W., Zhang, M. and Huo, B.	2009	IJPE	
	7	Zhao, X., Huo, B., Flynn, B. B. and Yeung, J. H. Y.	2008	JOM	
4	8	Zhuang, G., Xi, Y. and Tsang, A. S. L.	2010	IMM	225
5	9	Ke, W., Liu, H., Wei, K. K., Gu, J. and Chen, H.	2009	DSS	134
6	10	Terpend, R. & Ashenbaum B.,	2012	JSCM	225
7	11	Nyaga, G. N., Lynch, D. F., Marshall, D. and Ambrose, E.	2013	JSCM	242
8	12	Pulles, N. J., Veldman, J., Schiele, H. and Sierksma, H.	2014	JSCM	185
9	13	Brown, J. R., Lusch, R. F. and Nicholson, C. Y.	1995	JR	203
	14	Andrew Cox	1999	SCMIJ	
	15	Reimann, E. and David J. Ketchen, JR	2017	JSCM	
	16	Brito, R.P. and Miguel. P.L.S	2017	JSCM	
	17	Crook, T.R., Craighead, C.E. and Autry, C.W.	2017	JSCM	
	18	Webster, J.	1995	JSIS	
	19	heng, J., Li, B., Gong, B., Cheng, M. and Xu, L.	2017	JCP	
	20	Yu, D. Z., Cheong, T. S. and Sun, D. W.	2017	EJOR	
	21	Simson, D., Power, D. and Samson, D.	2007	IJOPM	
	22	Byne, R. and Power, D.	2013	SCMIJ	
	23	Gligor, D. M. and Holcomb, M.	2013	IJLM	
	24	Odongo, W., Dora, M., Molnar, A., Ongeng, D and Gellynck, X.	2016	BFJ	
10	25	Bandara, S., Leckie, C., Lobo, A. and Hewege, C.	2017	APJML	284

# **INTER-ORGANISATIONAL POWER: A STRUCTURED REVIEW AND IMPLICATIONS FOR FUTURE RESEARCH**

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## **ABSTRACT**

### **Purpose of this paper**

The development of power theory has been informed by knowledge from various disciplines of social sciences (Scott 1994). In the field of business study, power is at the centre of all business-to-business relationships (Cox 2001). While a significant amount of literature on power has been published in the past few decades, there is a lack of consensus on the theoretical and methodological bases of power studies (Gaski 1984). This study aims to contribute to addressing this shortfall through a structured review of literature on inter-organizational power (IOP).

### **Design/methodology/approach**

A total of 101 articles published between 1980 and 2014 were selected from 19 leading journals in the fields of logistics and supply chain management, marketing, and general business management. These articles were analysed with the focus on three aspects of the development of IOP studies: the distribution pattern of selected articles by journals, theoretical bases and methodological choices.

### **Findings**

A number of findings emerged: investigations into IOP in the field logistics and supply chain management of study are still underdeveloped; consensus is lacking on the supporting theories for the investigation of power; the positivist research paradigmatic stance is prevalent although a qualitative research approach has become increasingly popular.

### **Value**

The review identifies characteristics of the evolvement IOP studies since the 1980s. The originality of this paper lies in its analytical focus on theories and methodologies used to guide the investigations into IOP, which have not been examined to date. Drawing on the research findings, several implications are made to help future researchers identify research gaps and contribute to the development of the theory of power.

## **INTRODUCTION**

Inter-organisational relations affect the extent to which firms can coordinate production, combine and utilise resources, promote innovation, and achieve business success within the firm and across the supply chain (Martino and Morvillo 2008). Since logistics and supply chain management are characterised by interactive and integrated activities (Cooper and Ellram 1993, Mentzer et al. 2001), the study of inter-organisational relations has been a key theme for supply chain researchers who aim to understand the behaviours of supply chain members.

Power is one of the central and yet most problematic concepts in the sociological lexicon (Martin 1971). Before power was discussed in the business world, this concept had already been developed in other disciplines for decades (see e.g. Weber 1947, Hobbes 1951, French

and Raven 1959). According to Cox (2001) power is at the centre of all business-to-business relationships. The theoretical basis of IOP was first developed in the field of organisational sociology and industrial organisations (Provan et al. 1980). Several seminal works represent the origin of the conceptualisations of IOP including Simon (1953), French and Raven (1959), and Emerson (1962) (Simpson et al. 2013). The first two studies focus on the conceptualisation of power by investigating its bases (e.g. coercive power base, reward power base, legitimate power base), whereas Emerson (1962) interprets power through the lens of dependence relationship and the power of actor A over actor B equals the dependence of B upon A.

In addition to these seminal studies, established theoretical knowledge in various disciplines has been transferred to, and applied in, the domain of supply chain and business studies. While a significant amount of literature on power has been published in the past few decades, there is a lack of consensus on the theoretical and methodological bases of IOP studies (Gaski 1984). This paper aims to contribute to addressing this shortfall through a structured review of literature.

## **REVIEW METHODOLOGY**

This literature review mainly focuses on IOP studies in the context of logistics and supply chain management and general management. This paper reviews IOP studies between 1980 and 2014. 1980 was chosen as a start date so that the review covered the critical period in the development of supply chain management (Cooper et al. 1997, Tan 2001).

To maintain the quality of this review, the relevant articles were sourced from peer-reviewed journals. In total, 22 journals were searched, covering the fields of transportation, logistics and supply chain, marketing, and general management and strategy. The reason for incorporating marketing journals in this review was that the marketing context in which power has been studied is highly homogeneous to the context of supply chains (see e.g. Walters and Bergiel 1982, Rosenbloom 1990, La Londe and Masters 1994, Mentzer et al. 2001, Christopher 2001). As the concept of supply chain is relatively new compared to that of marketing channel, IOP research has drawn much more attention in the marketing literature than supply chain literature (Simpson et al. 2013). Thus, the source of IOP literature from marketing journals is necessary for an in-depth understanding of the development of IOP studies.

The search for articles was conducted using online databases (i.e. ABI/inform Global and Business Source Premier) and selected journals' websites. The keyword 'power' was used to source the articles. The search was limited to the title and abstract of the articles. In view of the conceptual diversification of power, a broad meaning of power, which is the ability to alter another's behaviours (Hunt and Nevin 1974, Taylor and Jackson 2000, Kahkonen 2014), was adopted in order to reduce the confusion caused by the multiple meanings of 'power' and filter out irrelevant articles. A full scan of the power-related articles was conducted, and only articles with a primary focus on IOP were included.

The search process generated 101 relevant articles from 19 journals with 3 journals sourced having no relevant papers published in the selected time period. A database of these articles was established. The analysis of these articles aimed to address the gap in the body of

power literature identified in Section 1. First, it provided an illustration of the general trend of IOP studies. Then it examined the primary source of data and the theoretical evolution of IOP research.

## FINDINGS

### General Trends

The distribution of articles by journal can be seen in Figure 1. The 19 deployed journals were categorised into four groups according to their targeted disciplines: logistics and supply chain (i.e. Journal of Purchasing and Supply Management (JPSM), International Journal of Logistics: Research and Applications (IJLRA), Journal of Business Logistics (JBL), Journal of Operations Management (JOM), International Journal of Physical Distribution and Logistics Management (IJPDLM), Journal of Supply Chain Management (JSCM), Supply Chain Management: An International Journal (SCM)), transportation (i.e. Transportation Journal (TJ), Transportation Research Part A (TRPA)), marketing (i.e. European Journal of Marketing (EJM), the International Journal of Research in Marketing (IJRM), the Journal of Marketing (JM), the Journal of Marketing Research (JMT), the Journal of Retailing (JR)), and general management (i.e. Academy of Management Journal (AMJ), Academy of Management Review (AMR), Administrative Science Quarterly (ASQ), British Journal of Management (BJM), Journal of Management Studies (JMS)). In general, the number of articles published in these four groups of journals was 40, 2, 44 and 15, respectively.

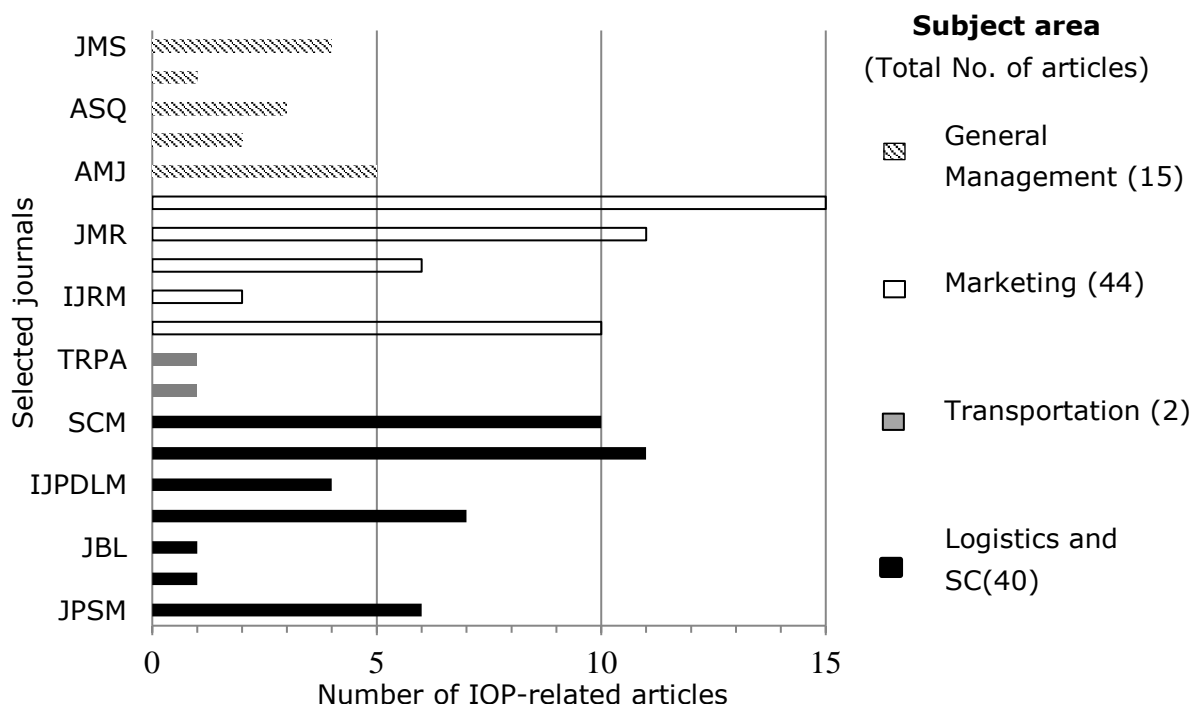


Figure 1: The distribution of IOP-related articles in 19 selected journals

When the transportation sector was categorised as a sub-dimension of logistics and supply chain management, the IOP articles were almost equally distributed between marketing and logistics and supply chain journals, although the total number of journals sourced from the latter domain was nearly double that from the field of marketing. This adds support to

the statement that power issues have attracted greater attention in the field of marketing than in supply chain and logistics studies (Ramsay 1996, Simpson et al. 2013). Overall, the three journals that had the most IOP articles were the Journal of Retailing, the Journal of Marketing Research, and the Journal of Supply Chain Management.

### Methodological Concerns

Researchers have used different data sources to deal with power enquiries. Table 1 presents the main data source of 67 empirical IOP studies out of the 101 articles selected. Five articles used multiple data sources. More than half of the empirical IOP studies used surveys or questionnaires for data collection. Structured interviews and experiments were each used in five articles. Documentary material was the major data source for eight articles, and qualitative interviews were used in 15 studies. The remaining two empirical articles had no relevant information.

Method	Count
Survey/questionnaire	37
Structured interview	5
Experiment	5
Qualitative interview	15
Documentary	8
Not indicated	2

Table 1: Data sources for IOP studies

Table 2 shows the evolution of data collection methods. Two categories were formed, which were structured/quantitative methods and less or unstructured/qualitative methods. Structured/quantitative methods included the first three methods in Table 1 and less or unstructured/qualitative methods covered studies that used qualitative interview methods. Seven articles that used documents as their primary data sources were not covered in Table 3, although their contents were generally quantitative. As seen in Table 2, the structured data collection method was widely adopted in IOP studies. Despite this popularity, the amount of research that used the structured data collection method has decreased since the 1980s. In comparison, the qualitative approach has been in general increasingly adopted by IOP researchers.

Method	1980s	1990s	2000s	2010s	Total
Structured/quantitative	18	11	10	8	47
Less or unstructured/qualitative	0	1	7	8	15

Table 2: Evolution of data collection methods of IOP studies

### Theoretical Concerns

The results about theories used in selected IOP studies are presented in Table 3. In general, 18 different theories were identified in 27 articles. These included both macro and micro theories, which implied that the conceptualisation of power had a wide scope. Although

there was no consensus in this classification, four theories (i.e. resource dependence theory, transition cost theory, agency theory and (social) exchange theory) were more frequently adopted. The remaining 14 theories were less commonly deployed. Whereas industrial organisational theory and game theory were each used in two articles, the other 12 theories (e.g. coalition theory and coercion theory) were used in only one article each.

<b>Theory</b>	<b>Frequency</b>	<b>Theory</b>	<b>Frequency</b>
Resource dependence theory	9	Bargaining theory	1
Transition cost theory	6	Coercion theory	1
Agency theory	5	Coalition theory	1
Exchange theory or Social exchange theory	4	Bilateral deterrence theory and conflict spiral theory	1
Industrial organisational theory	2	Behavioural theory	1
Game theory	2	Social network theory	1
Institutional theory	1	Social comparison theory	1
Relational exchange theory	1	Practice theory	1
Reciprocal action theory	1	Social capital theory	1

Table 3: Application of theory in IOP studies

## **DISCUSSION**

### **Descriptive Features**

During the selected period, the number of IOP studies in four marketing journals outnumbered those in five logistics and supply chain journals and five general management journals. This may have been due to the traditional interest in the topic of power in the discipline of marketing (Simpson et al. 2013). In comparison to these two disciplines, studies that had a primary focus on IOP were rarely found in the selected transportation journals. This implies that a focus on power in the transportation industry has been under-researched and thus important power related issues may have been overlooked.

### **Methodological Issues**

Structured methods had a wider application than unstructured or semi-structured methods. This implies a dominance of positivism in IOP research. This dominance has also been identified in the wider discipline of general supply chain and logistics research (Mangan et al. 2004, Mentzer and Kahn 1995, Naslund 2002, Sachan and Datta 2005). Even so, over recent decades there has been a noticeable growth in the use of qualitative data and a decrease of the use of quantitative data. This means that anti-positivism is increasingly applied in the field of IOP research, and researchers have begun to draw on in-depth data through multiple sources of information and using richer contextual details to deepen the understanding of the concept of power in various contexts.

### **Theoretical Issues**

The theoretical examination of IOP research deals with the theories used in IOP studies. Some theories are more commonly used in research studies than are others. This means there is a popular type of theory for IOP researchers. Conceptually, the commonly adopted

theories may present some original understanding of power. The findings of the distribution of IOP-related theories have also shown that, generally, each article adopts one theory to facilitate power research. In addition, it is noticeable that micro theories are much more frequently used in IOP research than are macro theories. This implies that IOP studies mainly focus on one dimension of power in terms of their content. This isolated approach to power research has a potential drawback since it seems to overlook the connections among different dimensions of power (e.g. the source of power and the exercise of power).

## CONCLUSION

The study of IOP has been a key theme for supply chain researchers who aim to understand the behaviours of supply chain members. While a significant amount of literature on power has been published in the past few decades, there is a lack of consensus on the theoretical and methodological bases of IOP studies (Gaski 1984). This paper has contributed to addressing this shortfall through a structured review of 101 IOP articles published between 1980 and 2014 in 19 leading journals in the fields of logistics and supply chain management, marketing, and general business management. The review has a number of implications for future research, as follows:

- Power is an essential area of study in inter-organisational research. Although the significance of this topic has been emphasised by a number of researchers, it is still overlooked, especially in the context of transportation, logistics and supply chain research. Thus, it is necessary to pay more attention to the research of power.
- Positivism and its related methodological toolkit have been widely adopted in IOP studies. This seems to be in contradiction to the context-specific feature of the concept of power (Kasabov 2007, Kim 2000). The study of power requires methods that can generate rich data which can appreciate the importance of the research context.
- Theories from various disciplines have been used to understand the complex concept of power. A comprehensive study that covers several key dimensions of power in one research context would be beneficial for the development of power theory.

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# THE ROLE OF RELATIONSHIP IN SUPPLY CHAIN COLLABORATION: A CONCEPTUAL FRAMEWORK

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## ABSTRACT

### **Purpose of this paper:**

This paper investigates the attributes of relationship as antecedents of supply chain collaboration and develops a conceptual framework depicting their roles in collaboration and impacts on firm performance. The study focuses on manufacturing firms in Asian countries.

### **Design/methodology/approach:**

A thorough review of extant literature was conducted to investigate the various attributes of relationship and their roles in supply chain collaboration. Taking into account the cultural and social differences between Asian and Western countries, we contend that current supply chain collaboration models and frameworks, which are mostly developed for developed economies, may not be totally applicable in the Asian business environment. The comprehensive literature review enabled us to develop a conceptual framework for investigating the roles of relationship attributes as antecedents of supply chain collaboration and their impacts on firm performance in the Asian context.

### **Findings:**

Based on social exchange theory, we identified from the literature various factors, such as trust, commitment, power, and reciprocity, as key attributes of relationship. They form the antecedents of supply chain collaboration. Also in Asian countries, business relationships involve significant amount of personal and organizational interactions. We therefore proposed that both inter-personal and inter-organizational forms of trust would need to be considered in the collaboration process. Hypotheses on relationships between the various attributes, collaboration and performance of the manufacturing firm were also put forward.

### **Value:**

The paper establishes the connections between various constructs about relationship in supply chain collaboration which have been researched individually or in group but not in a holistic manner. It therefore contributes to the understanding of the roles of relationship attributes in supply chain collaboration. It also provides insights and guidance for practitioners in the manufacturing industry in Asian countries to develop partnerships through supply chain collaboration.

### **Research limitations/implications:**

This study is conceptual in nature and needs to be supported by empirical evidence. The proposed conceptual framework can be validated in future studies using quantitative research techniques. Also, this study focuses only on collaboration in manufacturing industry in Asian countries. Future research can include other industries to enhance generalizability of the findings.

**Keywords:** supply chain collaboration, relationship attributes, manufacturing industry, Asian countries.

## 1. INTRODUCTION

In a highly competitive, globalized and turbulent business environment where rivalry is no longer between individual companies but entire supply chains, firms are increasingly aware of the needs to effectively manage supply chain activities beyond their boundaries (Patnayakuni *et al.* 2006). Since satisfying diverse customer needs could not be achieved through the effort of any individual firm, companies are confronted with the need to work closely and integrate with their supply chain partners through collaboration (Lejeune & Yakova 2005; Mentzer *et al.* 2000).

Supply chain collaboration can create mutual benefits and advantages, which could not be delivered inside any single organizational boundary, to supply chain partners (Mentzer *et al.* 2000; Verdecho *et al.* 2012). Collaboration would result in not only efficiency and responsiveness improvement, but also shared resources and knowledge leveraging (Cao & Zhang 2011). In addition, the success of collaboration helps firms to improve performance and sustain joint competitive advantages (Dyer & Singh 1998; Jap 1999; Mentzer *et al.* 2000; Mohr & Spekman 1994; Stuart & McCutcheon 1996). Supply chain collaboration has been defined differently by different authors, a summary of different definitions is provided in the Table 1. All of the definitions focus on the concept of 'sharing' and 'mutuality'.

No	Source	Definition
1	Simatupang et al. (2004)	Collaboration is a cooperative strategy of supply chain partners with a common goal of serving customer through integrated solutions for lowering cost and increasing revenue
2	Samaddar and Kadiyala (2006)	Collaborative relationship as one in which an organization initiates and implements a knowledge creation endeavour, and a collaborating organization shares the expense and benefits of newly created knowledge, including its joint ownership through patents and licenses
3	Fawcett <i>et al.</i> (2008)	The ability to work across organizational boundaries to build and manage unique value-added processes to better meet customer needs
4	Simatupang and Sridharan (2008)	Collaboration describes the cooperation among independent, but related firms to share resources and capabilities to meet their customers' most extraordinary or dynamically changing needs
5	Cao and Zhang (2011)	A partnership process where two or more autonomous firms work closely to plan and execute supply chain operations toward common goals and mutual benefits

Table 1: Definitions of supply chain collaboration

The essence of supply chain collaboration is to nurture a mutual relationship in which participants are willing to share information and resources and work together towards common goals (Samaddar & Kadiyala 2006; Simatupang & Sridharan 2008). A collaborative relationship is formed by at least two autonomous firms working together in planning and executing supply chain activities (Cao & Zhang 2011; Fawcett *et al.* 2008; Simatupang *et al.* 2004). According to the literature, the two major concerns for supply chain collaboration are the technical issue relating to information technology (IT) and the relationship issue relating to human interactions (Gunasekaran & Ngai 2004; Prajogo & Olhager 2012; Wei *et al.* 2012). It is emphasized that IT can only support but not replace human interactions which are considered as critical criteria of collaboration (Sanders 2007; Sanders & Premus 2005). Further, in the era of Internet, IT is well defined and widely adopted in most business organizations (Wu *et al.* 2014). Hence, relationship

issue, which could lead to meaningless connection and unwillingness to share information between partners if not properly resolved, is more vital to the success of supply chain collaboration (Sanders & Premus 2005; Wu *et al.* 2014).

Taking into account the cultural and social differences between Asian and Western countries, there were two different approaches to developing relationship. It can be developed at inter-personal level (Fan 2002; Wang 2007) as well as at inter-organizational level (Gummesson 1996; Morgan & Hunt 1994). Shaalan *et al.* (2013) contended that these approaches could simultaneously affect the mutual relationship between firms and emphasized the need of inter-personal approach in building the mutual relationship at inter-organizational level in Asian firms.

Collaboration, with its antecedents and consequences, can be linked and presented in a context-practices-performance framework of supply chain management as recommended by Ho *et al.* (2002). Antecedents are the preconditions or enablers of related supply chain management practices. Successful implementation of these practices is the key to achieving supply chain management objectives which are represented by the consequences (Lee *et al.* 2010). Although collaboration is considered a major supply chain management activity which has its antecedents and consequences, there has been little research investigating supply chain collaboration, its antecedents, and its consequences simultaneously (Lee *et al.* 2010).

This study proposes a conceptual framework for investigating the roles of relationship attributes as antecedents of supply chain collaboration and their impacts on firm performance in manufacturing industry in the Asian context. The relationship attributes are identified based on social exchange theory. The remainder of this study is structured as follows. A literature review on the antecedents of supply chain collaboration, components of supply chain collaboration, and consequences of supply chain collaboration will be presented. Then, a conceptual framework with hypothesis development will be discussed. Finally, conclusion and suggestions for further research will be made.

## 2. LITERATURE REVIEW

### 2.1. Antecedents of collaboration

Antecedents of collaboration could be categorized into two groups: technical related factors and relationship related factors (Gunasekaran & Ngai 2004; Prajogo & Olhager 2012). Technical factors, including IT capability and e-business applications, have significant impacts on collaboration through improving supply chain connectivity and integrated system (Fawcett *et al.* 2011; Sanders 2007; Sanders & Premus 2005; Wiengarten *et al.* 2013). In contrast, relationship issue can be approached from different perspectives including relational view (Zacharia *et al.* 2009), Guanxi & Xinyong (Cai *et al.* 2010; Lobo *et al.* 2013), social exchange (Wu *et al.* 2014), and miscellaneous (Chen *et al.* 2014; Ha *et al.* 2011; Lee *et al.* 2010; Min *et al.* 2005). Based on previous studies, antecedents of collaboration have been identified and given in the below Table 2.

Factors	Definition	Authors
Inter-personal trust	Inter-personal trust refers to the extent of trust of an individual in a focal firm on the counterpart in the supply chain partner	Zaheer <i>et al.</i> (1998), Ha <i>et al.</i> (2011), Lobo <i>et al.</i> (2013)
Inter-organizational trust	Inter-organizational trust refers to the extent of trust placed by a focal firm in the supply chain partner	Zaheer <i>et al.</i> (1998), Cai <i>et al.</i> (2010), Chen <i>et al.</i> (2014), Lee <i>et al.</i> (2010), Wu <i>et al.</i> (2014)
Commitment	Commitment is defined as an exchange partner's belief that an ongoing relationship	Morgan and Hunt (1994), Kwon and

	with another is so important as to warrant maximum efforts at maintaining it, that is, the committed party believes that the relationship endures indefinitely	Suh (2004), Zacharia <i>et al.</i> (2009), Lee <i>et al.</i> (2010), Wu <i>et al.</i> (2014)
Power	Power refers to the interdependence between partners, in which the decisions and behaviors of partners can be affected by the member with more power	Gaski (1984), Wu <i>et al.</i> (2014)
Reciprocity	The concepts of reciprocity in supply chains relate to the perception of common goals and mutual benefits which are core elements in constructing collaboration. Further, the belief of gaining reciprocal benefits in long-term facilitates information sharing between supply chain partners	Humphreys <i>et al.</i> (2001), Wu <i>et al.</i> (2014)
Guanxi	The term guanxi refers to networks of informal, personal relationships and exchanges of favors that dominate business activities	Cai <i>et al.</i> (2010)
IT capcability / E-business applications (EB)	IT capcability / EB can be defined as information systems to acquire, process, and transmit information for more effective decision-making, relative to competitive standards	Wiengarten <i>et al.</i> (2013), Sanders and Premus (2005)

Table 2: Antecedents of collaboration

The importance of the willingness to collaborate is always emphasized and the most important factor within various factors identified is trust. Whether in Asian or Western context, relationship plays a distinctive role in a partnership between supply chain members while technical issue can only support human interactions in a collaborative relationship (Lee *et al.* 2010; Sanders 2007; Sanders & Premus 2005).

In social exchange theory (SET), the interaction between entities or individuals with others can be explained based on the expectation of benefits from the relationships (Emerson 1976). In supply chain management, SET argues that the development of supply chain partnerships is based on the long-term mutual benefits gained from the relationships (Kwon & Suh 2005; Wei *et al.* 2012). Based on social exchange theory, trust, commitment, power, and reciprocity are identified as key attributes of relationship (Wu *et al.* 2014). According to Shaalan *et al.* (2013), because of the differences between Asian and Western cultures, relationship can be approached and developed at inter-personal level and inter-organizational level respectively. In particular, inter-organizational trust has significant impacts on collaboration (Cai *et al.* 2010; Chen *et al.* 2014; Lee *et al.* 2010; Wu *et al.* 2014), so does inter-personal trust (Ha *et al.* 2011; Lobo *et al.* 2013). However, in previous studies, the relationships between the different forms of trust and collaboration were examined separately.

This study therefore proposes the two forms of trust along with other relationship attributes to be antecedents of collaboration. Therefore, the antecedents of collaboration in this study include inter-personal trust, inter-organizational trust, commitment, power, and reciprocity.

## 2.2.Components of collaboration

Simatupang and Sridharan (2002) conducted a literature study on collaborative supply chain which could bring joint benefits to supply chain members. They proposed that appropriate performance measures, integrated policies, information sharing and incentive

alignment should be simultaneously considered, which was sufficient condition of the alignment of orientation issues and enabling issues in order to successfully obtain potential benefits. Information sharing and incentive schemes were emphasized as critical factors of successful collaboration leading to supply chain profitability. In a follow-up empirical study, Simatupang and Sridharan (2005a) developed a collaboration index incorporating information sharing, decision synchronization and incentive alignment. The results confirmed the high reliability and moderate validity of the proposed measure. Thereafter, based on the coherent collaboration construct of Simatupang and Sridharan (2005a), Wiengarten *et al.* (2010) identified the importance of information quality in the relationship between collaboration and operational performance. The results of their study showed that collaboration only had significant impacts on operational performance under high quality of exchanged information. The findings contributed to explain the contradictory results on the relationship between collaboration and performance from previous studies (Sanders 2007; Simatupang & Sridharan 2005a; Stank *et al.* 2001; Vereecke & Muylle 2006) in which information quality was not investigated. Fawcett *et al.* (2008) defined collaboration as resources sharing in terms of information, human and technology. Cao *et al.* (2010) further developed and interconnected the previous components and concepts into seven following components: information sharing, decision synchronization, goal congruence, incentive alignment, resource sharing, collaborative communication and joint knowledge creation contribute to the collaboration by cost reduction, quick response to changes, resource leverage and innovation improvement. Based on previous studies, components of collaboration have been defined and given in the below Table 3.

Factors	Definition	Authors
Information sharing	Information sharing refers to the exchange of confidential information among supply chain partners which focus on the accuracy, relevance and completion of information in timely manner	Simatupang and Sridharan (2002), Simatupang and Sridharan (2005a), Simatupang and Sridharan (2005b), Simatupang and Sridharan (2008), Sheu <i>et al.</i> (2006), Angeles and Nath (2001), Cao and Zhang (2010)
Goal congruence	Goal congruence refers to the engagement of supply chain partners in achieving common goal through collaboration	Simatupang and Sridharan (2005b), Angeles and Nath (2001), Cao and Zhang (2010), Lejeune and Yakova (2005)
Decision synchronization	Decision synchronization refers to the joint decision making process in supply chain planning and operations for the expansion and optimization of supply chain benefits	Simatupang and Sridharan (2005b), Harland <i>et al.</i> (2004), Cao and Zhang (2010)
Incentive alignment	Incentive alignment refers to the sharing process among collaborative firms in terms of costs, risks, and benefits	Simatupang and Sridharan (2005b), Angeles and Nath (2001), Cao and Zhang (2010)
Resource sharing	Resource sharing refers to the joint process of leveraging and investing tangible and intangible resources among supply chain partners	Simatupang and Sridharan (2005b), Harland <i>et al.</i> (2004), Cao and Zhang (2010)
Collaborative communication	Collaborative communication refers to frequency, direction, mode, and influence strategy of contacting and message transmission between collaborative partners	Mohr and Nevin (1990), Paulraj <i>et al.</i> (2008), Prahinski and Benton (2004), Cao and Zhang (2010)
Joint knowledge	Joint knowledge creation refers to the cooperation of supply chain	Kaufman <i>et al.</i> (2000), Malhotra <i>et al.</i> (2005), Cao and Zhang

creation	partners towards a better understanding of and responsiveness to the market and competitive environment	(2010)
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Table 3: Components of collaboration

To provide a comprehensive view of collaboration, this study leverages the components developed by Cao *et al.* (2010). Therefore, the identified components include information sharing, goal congruence, decision synchronization, incentive alignment, resource sharing, collaborative communication, and joint knowledge creation.

### 2.3. Consequences of collaboration

Without collaborative relationships, information, resources and materials cannot flow fluently in supply chains to achieve mutual benefits (Lambert *et al.* 2004). The success of collaboration can help firms acquire information from supply chain members (Gulati 1995; Koka & Prescott 2002), access shared resources (Park *et al.* 2004), share risks (Kogut 1988), reduce product development costs (Walter 2003), improve quality (Stuart & McCutcheon 1996), reduce transaction costs and improve productivity (Kalwani & Narayandas 1995), reduce logistics cost (Stank *et al.* 2001), improve innovation and technology-related capabilities (Powell *et al.* 1996), improve financial performance and create joint competitive advantages (Dyer & Singh 1998; Jap 1999; Mentzer *et al.* 2000; Mohr & Spekman 1994).

Consequences of collaboration in manufacturing firms can be categorized into operational performance in terms of cost and quality (Fawcett *et al.* 2011; Sanders 2007; Vereecke & Muylle 2006; Wiengarten *et al.* 2013; Zacharia *et al.* 2009) and business performance in terms of profit and sales (Cao *et al.* 2010; Cao & Zhang 2011; Lobo *et al.* 2013). From the perspective of manufacturing firms, this study proposes to investigate the impacts of collaboration on both operational and business performance.

## 3. RESEARCH HYPOTHESES AND CONCEPTUAL FRAMEWORK

Based on the literature review, we propose a conceptual framework including antecedents, components, and consequences of supply chain collaboration (Figure 1). Hypotheses about the linkages between the factors identified are also put forward.

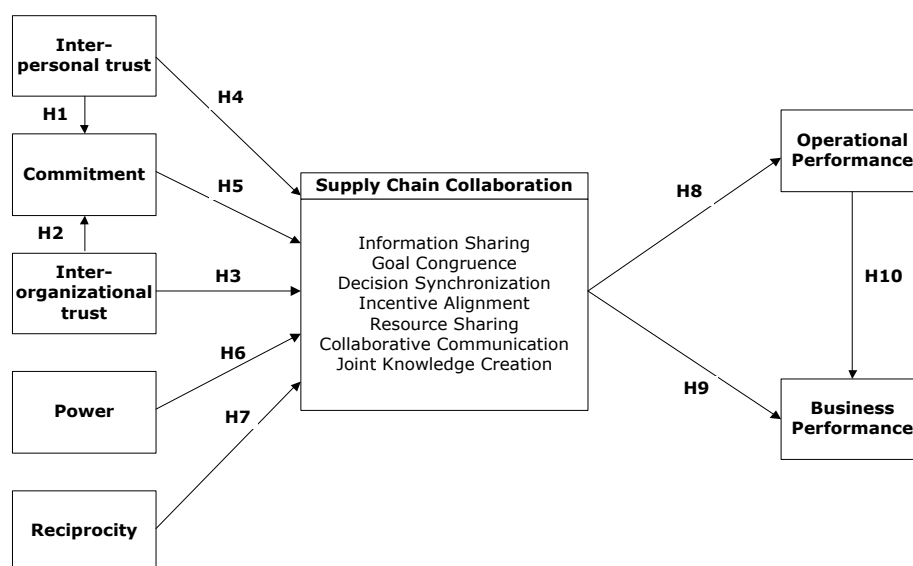


Figure 1: The conceptual framework



Trust has a significant positive impact on inter-organizational commitment (Morgan & Hunt 1994; Ryu *et al.* 2009; S. Tsanos *et al.* 2014). Trust can be regarded as inter-personal or inter-organizational relationship (Morgan & Hunt 1994; Zaheer *et al.* 1998). Morgan and Hunt (1994) theorized the relationship between trust and commitment in marketing relationship. The commitment-trust theory contends that for sustainable mutual benefits a firm wants to commit and develop the long-term relationship with other trustful supply chain partners. Besides, the study of Gulati and Sych (2007) showed that inter-personal trust also had a positive effect on commitment between business partners. Therefore, both inter-personal and inter-organizational trust must be considered in inter-organizational commitment and the relationship between trust and commitment can be hypothesized as follows:

**H1.** Inter-personal trust has a positive effect on commitment between supply chain partners.

**H2.** Inter-organizational trust has a positive effect on commitment between supply chain partners.

A number of studies suggest that inter-organizational trust is an antecedent of supply chain collaboration (Cai *et al.* 2010; Chen *et al.* 2014). Based on inter-organizational trust, business partners intend to fulfill their obligations in order to not only achieve mutual objectives but also maintain and develop strategic alliances, inter-organizational interactions and communication (Chen *et al.* 2014). A firm's trust in its supplier facilitates information sharing and collaborative planning between them (Cai *et al.* 2010). This expectation leads to the following hypothesis:

**H3.** Inter-organizational trust has a positive effect on collaboration.

Inter-personal trust is considered an antecedent of supply chain collaboration in a number of studies (Ha *et al.* 2011; Lobo *et al.* 2013). Ha *et al.* (2011) constructed inter-personal trust from affective trust and trust in competency, and confirmed the positive relationship between inter-personal trust and collaboration components including information sharing, joint decision making, and benefit/risk sharing. The study of Lobo *et al.* (2013) indicated that inter-personal trust in Chinese culture had significant positive effects on collaboration, inter-organizational relationship, and the supplier's financial performance. Hence, the following hypothesis is put forward:

**H4.** Inter-personal trust has a positive effect on collaboration.

Many studies argue that commitment positively improves the important supply chain management activities including information sharing and collaboration (Lee *et al.* 2010; Wu *et al.* 2014). Moreover, commitment plays an important role in maintaining the long-term relationship between trading partners and facilitates collaboration (Morgan & Hunt 1994). Thus, the following hypothesis is proposed:

**H5.** Commitment has a positive effect on collaboration.

In a partnership, a firm intends to exercise power over other firms if the firm perceives the possibility of inequity relating to the distribution of relationship resources and inputs into the relationship (Griffith *et al.* 2006). Hence, power is suggested as the parameter of exchange in supply chain partnerships (Narasimhan *et al.* 2009). A more powerful firm in supply chain may control over other supply chain members in information sharing resulting in more effective collaboration (Hart & Saunders 1997). Accordingly, the following hypothesis is proposed:

**H6.** Power has a positive effect on collaboration.

Based on social exchange theory, relationships are formed and developed because a member can gain reciprocal benefits from others over time (Narasimhan *et al.* 2009). Reciprocity helps suppliers access accurate and up-to-date information from downstream partners to facilitate production management. As a result, responsiveness, which relates to the benefit of buyers, can be improved (Wu *et al.* 2014). Hence, the following hypothesis is proposed:

**H7.** Reciprocity has a positive effect on collaboration.

Many scholars contend that supply chain collaboration has the positive impact on operational performance (Lee *et al.* 2010; Nakano 2009; Sanders 2007; Sanders & Premus 2005; Simatupang & Sridharan 2005a; Wiengarten *et al.* 2010; Wiengarten *et al.* 2013; Zacharia *et al.* 2009) and business performance of the focal firm (Cao *et al.* 2010; Cao & Zhang 2011; Zacharia *et al.* 2009). Operational performance relates to cost reduction, cycle time reduction, quality improvement, and service or value improvement (Koufteros *et al.* 2002). At the firm level, business performance relates to growth of sales, return on investment, growth of return on investment, and profit margin on sales (Cao *et al.* 2010; Cao & Zhang 2011). Hence, the following hypotheses are proposed:

**H8.** Collaboration has a positive effect on operational performance.

**H9.** Collaboration has a positive effect on business performance.

Firms need to invest its resources in maintaining long-term relationships with business partners in order to have greater returns including higher sales from the collaborative relationship (Kalwani & Narayandas 1995). Zacharia *et al.* (2009) suggested a positive relationship between operational performance and business performance at the firm level. Hence, the following hypothesis is proposed:

**H10.** Operational performance has a positive effect on business performance.

#### **4. DISCUSSION**

This study establishes the connections between the various constructs about relationship in supply chain collaboration which have been researched individually or in group but not in a holistic manner. Relationship issue is identified as the core content of supply chain collaboration (Gunasekaran & Ngai 2004; Prajogo & Olhager 2012; Wei *et al.* 2012). However, in different cultures and contexts, relationship could be built and developed at different levels including firm and individual (Shaanan *et al.* 2013) and collaborative relationship is no exception. The literature shows that collaboration could be developed at inter-organizational level (Cai *et al.* 2010; Chen *et al.* 2014; Lee *et al.* 2010; Wu *et al.* 2014) and/or inter-personal level (Ha *et al.* 2011; Lobo *et al.* 2013). The impacts of the two approaches in a business-to-business relationship need to be investigated simultaneously in different contexts (Zaheer *et al.* 1998), especially, in Asian countries (Shaanan *et al.* 2013).

The proposed conceptual framework investigates the roles of relationship attributes at inter-organizational and inter-personal levels as antecedents of supply chain collaboration and their impacts on firm performance in manufacturing industry in the Asian context. Based on social exchange theory, various factors, such as trust, commitment, power, and reciprocity, are identified as key attributes of relationship. In particular, both inter-personal and inter-organizational forms of trust would need to be considered. Further, the relationship between each form of trust and commitment is proposed based on the commitment-trust theory developed by Morgan and Hunt (1994). This provides a theoretical underpinning to examine the role of trust towards relationship commitment between firms.

This study therefore contributes to the understanding of the roles of relationship attributes in supply chain collaboration. It also provides insights and guidance for practitioners in the manufacturing industry in Asian countries to develop partnerships through supply chain collaboration.

Nonetheless, this study is conceptual in nature and needs to be supported by empirical evidence. The proposed conceptual framework can be validated in future studies using quantitative research techniques. Also, this study focuses only on collaboration in manufacturing industry in Asian countries. Future research can include other industries to enhance generalizability of the findings.

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# COORDINATED DECISION MAKING AMONGST STAKEHOLDERS WITH DIFFERENT INTERESTS: A CASE STUDY IN PARTS HARVESTING FOR MEDICAL SYSTEMS

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## Abstract

**Purpose:** To investigate to what degree sharing of information improves coordinated decision making amongst multiple internal stakeholders within the parts harvesting closed loop supply chain in medical systems.

**Design/methodology/approach:** The case is selected as a typical case. We use linear programming to compare several scenarios. Solutions are optimized in a basic scenario for the harvesting department only. Yield reduction, known availability of material resources (a.k.a. cores) and demand variation are tested in sensitivity analysis. Then the model is extended with another stakeholder (service department) into the integral scenario where decisions are coordinated.

**Findings:** Surprisingly, endogenous variables related to harvesting, have far less impact than exogenous variables like demand or yield. Both types are constrained by antecedent factors, e.g. eco-design, business model, installed base monitoring system.

**Value:** We apply a stakeholder approach to a complex parts harvesting operation, specifically we research whether information sharing facilitates coordinated decision making among stakeholders. We discuss endogenous, exogenous variables, antecedents and the generic value of the case.

**Research limitations/implications:** Future research should primarily aim at relaxing antecedent factors so coordinated decision making will be more beneficial.

**Practical implications:** Companies should first work on issues related to antecedent factors to create more possibilities for coordinated decision making and information sharing. Until then, stakeholders may share information but are advised to take decisions on their own, since benefits may not be seen integrally across departments.

## 1. INTRODUCTION

Closed Loop Supply Chain (CLSCs) management combines forward and reverse supply chain management and aims to “maximize value creation over the entire life cycle of a product with dynamic recovery of value from different types of return over time” (Guide & Van Wassenhove 2009, p.10). Creating value from CLSC management requires the *coordinated decision making* across various forward and reverse supply chain activities, including forecasting of supply and demand (Krapp et al., 2013) or logistics and transportation (Das & Chowdhury, 2012). CLSC activities involve different supply chain *stakeholders* such as customers, suppliers, and retailers who significantly influence CLSC processes with possibly conflicting views (Choi et al., 2013). To create value from CLSC management, manufacturers should aim at integral thinking among internal stakeholders (Schenkel et al., 2015), rather than locally optimizing processes. However, to date, few CLSC studies have investigated this (Kleber et al., 2011; Zhang, 2013). Current literature is limited to holistic optimization models (Fleischmann et al., 2003) and studies on value creation in CLSCs from a single actor point of view (Kumar & Craig, 2007). Others conduct system dynamics modelling on reverse logistics and harvesting, thereby adding to studies such as Kumar et al. (1994) who simulated simple return flow systems with repair, and Tang and Naim (2004) who used system dynamics modelling in a scenario where reverse logistics impacts on original equipment inventories.

This paper contributes to the literature by empirically researching integral value creation by coordinated decision making among stakeholders in a parts harvesting CLSC. We compare a situation where only a single actor ‘harvesting department’ optimizes the product acquisition, recovery and re-use related decisions, with scenarios that include the alignment of interests of multiple internal stakeholders who are willing to share useful information. Our study takes place in medical systems, which is an international manufacturer of high-capital medical equipment. For years, the company is industry-wide well known for its refurbishment practices and recovery of parts from returned material sources. We specifically study the parts harvesting supply chain that supplies spares. Parts recovery describes the process of trade-in, return, disassembling and sorting returned products and parts with the aim to harvest, test, and, if needed, repair valuable parts for future use in the installed base.

## 2. LITERATURE

While many studies researched operational issues related to recovery options few studies focused on harvesting as a recovery operation (e.g. Fleischmann et al., 2003; Spengler & Schröter, 2003). Harvesting implies that recovered parts can be used as substitutes for new service parts, which can reduce sourcing costs, and, in the case of end of supply, shortage costs for not fulfilling service level agreements (Krikke and van der Laan, 2011). Meanwhile, part recovery is not constrained by market cannibalization effects or short product lifecycles, which would impede product recovery (Fleischmann et al., 2003). The quantity and timing of used parts and products that are pushed back to the focal company depend on the customers’ willingness to return or trade-in their products (Guide, 2000). As a result, inventory, production and disposition planning require tailored models (Inderfurth and Kleber, 2013) when harvesting is implemented.

Stakeholder theory suggests that in order to stay competitive and create business value, companies need to integrate the interests and demands from a variety of stakeholders



(Freeman et al., 2004). A premise to coordinating decisions in CLSCs is *information sharing* to align the interests of stakeholders in the CLSC. Stakeholders influence information flows in CLSCs, such as information about product returns, which are crucial to the CLSC performance, including parts harvesting operations (Mihi Ramírez, 2012; Schenkel et al., 2015; Huiskonen, 2001).

CLSCs constitute forward and reverse supply chain stakeholders who can significantly influence the performance and value creation of the CLSC (Wong et al., 2012). Literature distinguishes between primary and secondary stakeholders groups (Clarkson, 1995). While primary stakeholders, such as suppliers or customers, are involved in corporate transactions and can influence corporate decision making, secondary stakeholders, such as societies, NGO's or the natural environment, are affected and influenced by corporate activities (Clarkson, 1995). Parts recovery and planning are complex operations due to high service requirements, potential financial losses due to stock-outs, last time buys, or strong fluctuations in demand.

In sum, alignment of interests, information sharing and collaboration between stakeholders are crucial for managing the parts harvesting supply chain effectively. To date, few studies deliberately modelled the effects coordinating decisions of different stakeholders in CLSC parts harvesting operations.

### **3. METHODOLOGY**

We choose to work in capital intensive industries with long product life cycles as one finds most parts harvesting operations there. We sampled this company in particular because it has a relatively advanced parts harvesting system and an ambitious circular economy program had just been installed. Our study is conducted at one brand owner in an in-depth case study setting. As such, this research is a follow up of (Schenkel et al., 2015), which provided a more general view based on qualitative research with four brand owners. The parts harvesting supply chain includes three stakeholders: The Harvesting Department as the focal company, the Local Organizations as the internal supplier, and the Service Organization as the internal customer. The Harvesting Department receives a monthly total demand for spare parts from the Service Organization. Parts are harvested from returned material sources which can either be parts returned from upgrades, or used product traded in. Given the fact that the material sources belong to similar product families, more than 50% of the parts are present in more than one material source. The 'yield' describes the probability of harvesting a reusable part from a material source. Harvested parts are put on stock before the delivery to the service organization. In case the full demand for parts cannot be fulfilled by the Harvesting Department, the Service Organization may source new parts from suppliers, but only as a second option. Stocking of harvested parts costs money, so the Harvesting Department may decide at some point to scrap reusable parts that are in low demand. The Service Organization pays the Harvesting Department per part delivered by them. Prices can be 30% below new price. Exogenous variables are tested by sensitivity analysis.

In our analysis we use linear programming (LP) to compare several scenarios. The base scenario considers the situation where only the Harvesting Department optimizes its decisions about take back of material sources, recovery (repair or scrap) and temporary stocking of recovered parts. Yet, information sharing between the Sales Organizations

and Harvesting Department can increase the amount of available product returns. The different material sources define which parts The Service Organization may lower or increase the demand for parts. Part demand depends on market developments, supplier relationships, excess inventory at the service organization or last time buys that influence the inventory and purchase of new parts. To optimize decisions of both departments in a coordinated fashion, we adapt the LP model with a common profit and loss account of the Harvesting Department and Service Organization. This is called the integral scenario. Table 1 overviews each stakeholder's interests and shows the modelling of these interests in our scenario.

	<b>Harvesting Dep.</b>	<b>Sales Organizations</b>	<b>Service Department</b>
<b>Stakeholder interest</b>	Maximize amount of harvested parts	Reduce the lead & installation time of upgrades and de-installation of trade-ins	Deliver on time and with the highest quality to the customer.  Manage own inventory and keep the service levels high for customers by dual sourcing parts from suppliers and the Harvesting Department.
<b>Influence on harvesting</b>	Harvest as many parts as demanded	Decide when to return parts depending on quality of material sources either are worn out or badly disassembled  Provide information to harvesting dep. about product upgrades or trade-ins	Manage fluctuating demand  Common goal of maximizing profits from harvesting
<b>Sensitivity Analysis</b> (exogenous))	Higher or lower availability of material sources	Lower harvesting yield	Higher or lower demand for harvested parts
<b>Decision var.</b> (endogenous)	Basic scenario	Within basic scenario	Integral scenario

**Table 1. Overview stakeholders and modelling**

Our dataset comprises a time period of six months. We assume that by the end of this time period, harvesting activities have to be phased out. We include several hundred types of parts that can be harvested from six different material sources from four different regions. The demand for parts fluctuates. The different types of parts demanded differs in each period, but in all time periods, all part types are demanded. All parts are supplied, recovered and demanded in the given time period and initial yield is set to 1 but lowered later. Backordering of unsatisfied demand is not permitted. We include lead times as material sources are returned in one month, (e.g. to) and harvested and

delivered to the Service Organization in the following months (e.g.  $t_{1-6}$ ). Parts for which there is no demand until the end of the planning period, or inventory of parts that exceed the cumulative demand until the end of the planning period will be scrapped. In order to limit the length of the paper we will not present the full model as it is a fairly standard case of linear programming.

#### 4. RESULTS

Table 2 summarizes results including the antecedent factors which will be discussed in more details in section 5. Below we elaborate on some remarkable findings.

	<b>Harvesting department</b>	<b>Sales Organization</b>	<b>Service department</b>	<b>Antecedent Factors</b>
<b>Base scenario optimized</b>	Profitable	High return rate	Fill rate up 28-53%	Customers' willingness influences return rate
<b>Improved information on resource availability</b>	Higher, more homogeneous volumes, profits up by 20%	Return rates up	Fill rate even 10% higher	No Installed base monitoring (IT)
<b>Yield down</b>	Profits down by 20-40%, more scrap	Higher cost of de-installation	% of reused parts down	No product eco design
<b>Demand up</b>	More profit up to 50%	Return rates up	% of reused parts up down	Business model traditional
<b>Demand down</b>	Less profit up to 50%  Stock of reused parts up	Return rates not down significantly	Excess stock	Need of possibilities for system upgrades limited
<b>Integral scenario</b>	Not profitable, but losses overcompensated by Service Dep profits	Return rate +20%	Profitable, total cost down by 2%, other values improve	Centralized reverse network

**Table 2. Summary of results per stakeholder and antecedent factors**

The results of the basic scenario show that harvesting is profitable. The return of material sources is determined by the value of the *known* parts that they contain. Information sharing affects the parameter "availability of material sources" positively and potentially increases volumes and profits. Flows become more homogenous, i.e., higher volumes of fewer types of returns, and also mono flows from remote areas from are now collected. Increased demand increases profits but reduces the percentage reused parts and vice versa. Lowered yield lowers profits by as much 20-40% and poses a significant issue. We

modelled integral value creation by allowing the harvesting department to make losses for reducing the total purchasing costs for new and harvested parts at the benefit of the Service Department. More material sources are returned, but total cost only lower by 2% when decisions are coordinated. All scenario's suffer from relatively high logistics cost. Material sources are cores, i.e. full systems containing parts. Cores are returned from across the globe and disassembled into parts in the centralized harvesting department. Only a part of them is feasible for reuse, the others are scrapped. They are returned from across the globe and disassembled into parts in the centralized harvesting department. Only a part of them is feasible for reuse, the others are scrapped at the Harvesting location.

## 5. DISCUSSION AND CONCLUSION

Our study used linear programming to model the effects of coordinating decisions amongst different stakeholders in parts harvesting operations. We compared several scenarios, each of which inspires different interests for each stakeholder. We see that exogenous variables, including yield, demand and availability of returns, have a higher impact than endogenous variables. The availability of returns is positively influenced by sharing information on material resources. However, information sharing is constrained due to a lack of installed base monitoring. This could be overcome if the Sales organization and Harvesting department would have IT systems that support assessing the availability of returns in the installed base (Fleischmann et al., 2003). Please note that sharing information increases the amount of *known* material resources. The actual amount of returns depends on willingness of the sales organization to actually return materials. Both return volumes and yield factors are often lowered due to difficulties in removing and de-installing system at the customer site, which occurs under time pressure. Product eco-design, in particular design for disassembly, should be considered as relevant antecedent factor as it eases disassembly and enables testing and recovery.

Provided that information about availability of returns is shared, one would expect coordinated decision making to pay off. Surprisingly, in the integral scenario the total purchasing costs only slightly decrease. One explanation could lie in the relatively high logistics cost. Due to the centralized network, certain parts are pulled towards the harvesting department, but additive parts with no demand are also returned (pushed) and ultimately scrapped (Krikke & van der Laan, 2011). A solution could be to introduce a local pre-selection of valuable parts and scrapping of non-valuable parts. Logistically, homogenous flows might reduce costs, but heterogeneous set of harvested parts can be beneficial to avoid last time buys or future shortage of supply. Also, unnecessary and/or difficult system upgrades at the customer could be avoided by ensuring the supply of parts via harvesting. Finally, an increase in trade-ins enabled by harvesting created the commercial opportunity for selling new/refurbished products and services. However, traditional business models are not geared for reuse and should be reconsidered to implement this option (Ostlin et al., 2008).

This study emphasizes the importance of assessing the interests of the involved stakeholders in each situation. As such it contributes to the literature that pleads for holistic optimization models (e.g. Fleischmann et al., 2003) and a holistic view of stakeholder management (Smudde and Courtright, 2011).

Our case can be characterized as parts harvesting in a global, capital intensive, industry. The systems have long life cycles and the installed base is designed to be supported for long periods of time. Often service level agreements apply and during the life cycle, system upgrades will occur. The reverse chain is controlled by a hybrid push-pull approach, but decisions are taken by multiple stakeholders. Material sources (cores) are returned to a central facility and disassembled into reusable and additive, non-reusable parts. Due to the high obsolescence risk, companies generally prefer harvesting over buying new, but (low) yield poses a risk. After the last time buy of new parts, one usually completely relies on parts harvesting until the system is phased out by the last customer. We generally deal with slow movers and demand is uncertain.

Our study has several limitations. This study is conducted at one brand owner in an in-depth case study setting. Real data from more cases could test the findings in this study. Cases should be sampled according to the generic features mentioned but preferably differ in the way they deal with antecedent factors so we can understand their impact on profits and other performance. Other limitations of this study include the single-supplier/single-customer approach. While this study assumed that parts are only delivered to the Service Organization, harvested parts could also be re-used in refurbished products. Multi-channel, multi-loop CLSCs and their impact on integral value creation could be further investigated in the future (Krikke, 2010). It should thereby focus on relaxing the antecedent factors discussed.

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# STRATEGIC SUPPLIER EVALUATION BY A JEWELRY FIRM IN THAILAND

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## ABSTRACT

**Purpose** The design and production of annual collections of famous brand jewelry is heavily dependent on the reliability of suppliers of gemstones. The firm, JEWELZ, was fearful of the risk of supplies not being of high quality or on time. This research paper identifies the correct supply positioning of Cubic Zirconia and Nanocrystal using portfolio analysis and determines appropriate relationships with suppliers of Cubic Zirconia and Nanocrystal.

**Design** The methodology is to use 2014/2015 data to analyze suppliers' performance and relationships, as well as tactics and actions of a strategic relationship. Collaboration evidence is obtained from interviews with internal and external stakeholders. Evaluation scores for the four suppliers are decided by cross-functional teams which deal with these suppliers or are affected by suppliers' performance.

**Findings** Research discovered that the firm's buyers selected suppliers based only on their personal decision which was not based on firm-related criteria, and that there were no strong relationships with suppliers. A risk/profitability matrix identified in which of four quadrants each type of gemstone was positioned; they were either bottleneck, strategic, non-critical, or leverage gemstones. The characteristics of each quadrant determined how each supplier should be managed, in terms of strategies, tactics, and action. Out of 47 suppliers, 4 were found to be the significant main suppliers, each having different abilities in supporting JEWELZ, and all wanting to supply more. Two suppliers were found to be in the critical and leverage quadrants, justifying a collaborative relationship.

**Value** This research is a case study of a world-class jewelry firm that provides the contribution to the existing research as there is a lack of study focusing on the collaborative relationship in the jewelry industry. It has proven that the tools related to the supply chain analysis are workable with the relationship management of suppliers of Cubic Zirconia and Nanocrystal, who are in the part of jewelry business.

**Research Limitations** The major limitation of this research is the short window of demand forecast that the marketing team can provide to the supply chain team. The importance of each supplier might be different from the result of the current study, if the trend of the demand after the next six months is significantly changed.

**Practical Implications** The proposed collaborative plan was accepted and implemented by the company and its external partners. Other companies might profit from this report.

**Keywords:** SUPPLIER EVALUATION, JEWELRY, COLLABORATION

## 1 INTRODUCTION

Exotic jewelry with a famous brand name has to be top quality. Suppliers of the basic materials have to be reliable for quality and on-time delivery. Fierce competition and customer choice pressurize many jewelry firms, who respond with creative design strategies. Product quality is dependent on the workforce, but also on the supply of raw materials. Reliable suppliers have to be identified and evaluated. The focus firm, JEWELZ, is reviewing its sourcing policy to reduce the supplier base and cultivate a strong relationship with those remaining. The two research objectives are to identify the correct supply positioning of Cubic Zirconia and Nanocrystal using portfolio analysis, and to determine appropriate relationships with suppliers of Cubic Zirconia and Nanocrystal.

### 1.1 Background of the Research

JEWELZ (a pseudonym) is a world-class jewelry firm. Its jewelry products are made in Thailand and exported to 50 countries and 9,000 sales outlets, and are important to Thailand's economy. This brand is renowned for its high-quality hand-finished, jewelry at affordable prices. The company designs, manufactures and markets modern jewelry made from silver or gold, inset with natural and synthetic gemstones. The process begins with in-house design. After manufacturing, the jewelry is directly distributed to global markets.

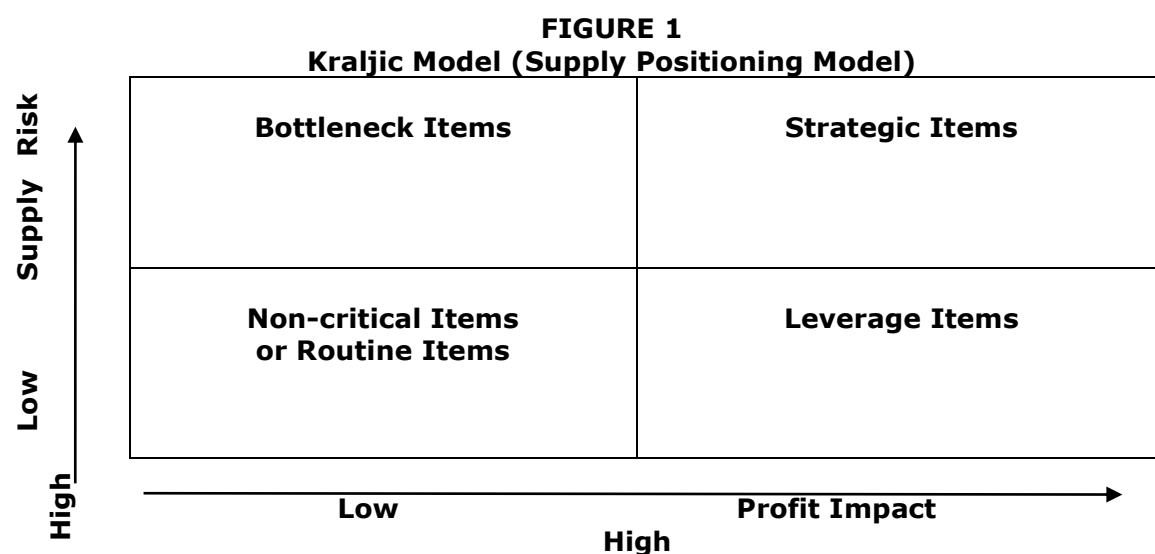
In 2015, JEWELZ produced 80 million pieces of jewelry, an expansion of 12% over 2014. The basic materials are precious metals and gemstones. This study focuses on four types: Cubic Zirconia (CZ) which is a diamond imitation, Nanocrystal, Synthetic Stones, and Natural Stones. CZ has two colour sub-types: Treated Colour, and White-Normal Colour. The CZ proportion of total gemstone spending in 2015 was 75%. Gemstones are bought from 74 suppliers, each with different capacities, abilities, and purchased quantities.

## 2 LITERATURE REVIEW

This study uses theoretical contributions from published research to examine the under-researched collaborative relationships in the jewelry industry. It is critical to manage suppliers strategically (Anderson, Britt, & Favre, 2007). Effective links between suppliers and manufacturers enable strategic supply management to minimize costs, add value, create competitive differentiation, and form trusting bonds to achieve shared objectives.

### 2.1 Deriving Strategy from a Firm's Position in the Supply Matrix

Handfield et al. (2009) said that the tool most often used to categorize a firm's supply base, is the portfolio analysis matrix (usually called the Kraljic Model) which plots profit against risk, resulting in four quadrants.





The horizontal axis (Profit Impact) indicates the potential of the supply to contribute to the profitability (or efficiency) of the buyer. The vertical axis (Supply Risk) is the degree of difficulty in sourcing a product or service, or the vulnerability of the buyer to a failure of the supplier to provide as agreed and on time (Baily, Farmer, Jessop, & Jones, 2005). A summary of the four quadrants in this matrix shows the characteristics of each and how they should be managed in terms of Strategies, Tactics, and Actions, as in Table 1 below.

**TABLE 1**  
**Managing Different Quadrants in the Kraljic Model**

<b>Characteristics</b>	<b>Strategies</b>	<b>Tactics</b>	<b>Actions</b>
<b>Strategic or Critical items:</b> Critical to profitability and operations, few qualified sources of supply, large expenditures, design and quality critical, complex and/or rigid specifications	Form Partnership with suppliers	Increase role of selected suppliers	Heavy negotiation, supplier process management, prepares contingency plans, analyze market/ competition, use functional specifications
<b>Bottleneck items:</b> Complex specifications requiring complex manufacturing or service process, few alternate productions/sources of supply, big impact on operation/ maintenance, new technology or untested process	Ensure Supply Continuity	Decrease uniqueness of suppliers, manage supply	Widen specification, increase competition, develop new suppliers, Medium term contracts, attempt competitive bidding
<b>Non-Critical or Routine items:</b> Many alternative products and services, many sources of supply, Low value: small individual transactions, everyday use, unspecified items, anyone could buy it	Simplify Acquisition Process	Increase role of systems, reduce buying efforts	Rationalize supplier base, automate requisitioning, stockless procurement, minimize administrative costs, little negotiating
<b>Leverage items:</b> High expenditures, commodity items, large marketplace capacity, ample inventories, many alternative products and services, many qualified sources of supply, market/price sensitive	Maximize Commercial Advantage	Concentrate business, maintain competition	Promote competitive bidding, exploit market cycles/ trends, procurement coordination, use industry standards, active sourcing

**Source:** Bozarth and Handfield (2013, p. 222)

**Strategic or Critical items** need close co-operation with suppliers which will lead to improvement in product quality, delivery reliability, lead times, product development and design, and cost reduction (Tuben & Urban, 2001).

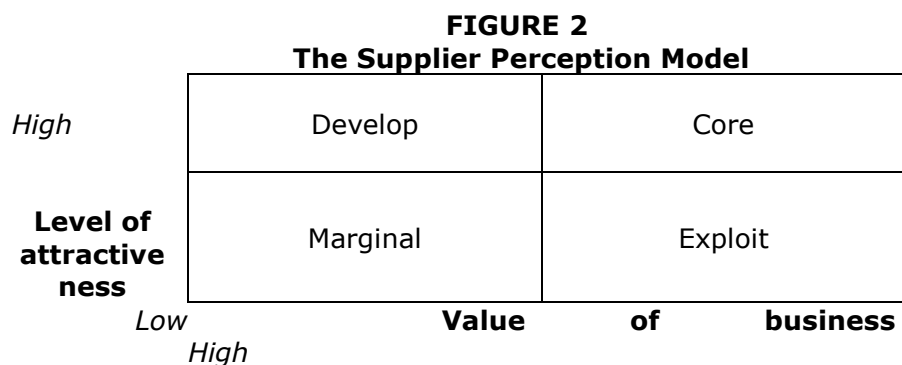
**Bottleneck items** give the supplier a dominant power position (Kempenens & Van Weele, 1997). Items considered bottleneck should be bought from suppliers who regard a buying organization as a customer to develop (ITC, 2000).

**Leverage items** give the buyer a dominant power position (Kempenars & Van Weele, 1997), with blanket orders.

**Non-critical or Routine items** make the dependence of the buyer and the supplier both quite low. A buyer should enhance purchasing power by standardization and bundling of purchasing requirements (Kempenars & Van Weele, 1997).

## 2.2 A Supplier Perception Model

It is essential to assess a supplier's perceptions of the buying firm. According to ITC (2010), the result from the assessment is an understanding of whether the supplier is interested in developing a strong working relationship. A model of this perception assessment is based on two dimensions: the value of the supplier's business with the firm, and how strongly the supplier finds the buyer attractive and desired. Plotting these two dimensions produces four categories, shown in Figure 2.



**Source:** ITC (2010)

## 2.3 Supplier Evaluation

Lysons and Farrington (2006) stated that there are four situations in which appraisal or evaluation of a supplier is essential: purchase of strategic high-profit, high-risk items; purchase of non-standard items; supplier development (what needs to be done to bridge the gap between the present resources and competences of a supplier and the standard required by the purchaser); and when negotiating a service-level agreement.

Lysons and Farrington (2006) suggested a supplier rating method, which has a weighting factor for each area, which indicates the value of that area in relation to the others. A score is first assigned to each factor to indicate the supplier's performance. This score is then multiplied by an assigned weight and then averaged.

Carter (1995) introduced the ten Cs of effective supplier evaluation: These are 1) competence, 2) capacity, 3) commitment, 4) control system, 5) cash resources and financial stability, 6) cost, 7) consistency, 8) culture compatibility, 9) clean and compliant performance, and 10) communication.

## 2.4 Types of Supplier Relationship

Lang et al. (2002) proposed that appropriate strategic supplier relationship management (SRM) is critical to a firm's sustained profitability. CIPS (2011) classified two main supplier-buyer relationship. The basic type is a simple *Transactional Relationship* wherein neither party is especially concerned with the well-being of the other, and focuses mainly on price. A higher type is a *Collaborative Relationship* which requires trust building, communications, joint efforts and planning. This relationship increases the likelihood of investments in R&D, training, and procurement of new, more efficient equipment. A high degree of trust enables access to each other's strategic plans, and cross-functional teams. Relevant cost information and forecasts are shared. Risk and reward are addressed openly. The total cost can reduce due to synergies, time to market

can be reduced thus improving quality and continuity of supply. This relationship is very resource-intensive.

## **2.5 Supply Chain Collaboration**

According to Handfield et al. (2009) collaboration is the process by which two or more parties adopt a high level of purposeful cooperation to maintain a trading relationship over time. Collaboration is about setting up the supply chain to lower overall cost and then sharing the savings (Cohen & Roussel, 2005). Mutual commitment to the future and a balanced power relationship are essential to the process. Mangan et al. (2012) added that collaboration is dependent on the provision of mutual benefit. It is not necessarily an equal benefit sharing but an equitable sharing (Cohen and Rooussel, 2005). A rich information exchange is the ideal for true supplier partnerships to work collaboratively (Benton, 2014).

## **3 RESEARCH METHODOLOGY**

The methodology is to use 2014/2015 data to analyze suppliers' performance and relationships, as well as tactics and actions of a strategic relationship. Collaboration evidence is obtained from interviews with internal and external stakeholders. Evaluation scores for the four suppliers are decided by cross-functional teams which deal with these suppliers or are affected by suppliers' performance.

Data analysis produces details of historical purchases by suppliers, the supply positioning model, quantity and value of gemstones in current orders and demand forecasts, and competitive priorities. Gap finding elicits a missing buying decision model that could impact JEWELZ mission and competitive advantages through supplier motivation and continuous improvement.

Statistics for two years from the JEWELZ computer database reveal the purchased volume of gemstones from each supplier, and a demand forecast for the next 6 months. This information is used to analyze the characteristics of each sub-group of gemstones, leading to selecting an appropriate relationship strategy with each supplier.

### **3.1 Interviews**

Interview are held with stakeholders. The *internal* stakeholders are heads of each department: creative and design; quality control; and logistic and planning (the purchasing team and Corporate Social Responsibility team, are within the logistic and planning department). The *external* stakeholders are suppliers who provide gemstones to JEWELZ.

These interview provide an understanding of the competitive strategy and priorities. Priorities are a key determinant of the importance given to different criteria in purchasing materials. Those criteria are (i) cost, (ii) quality level, (iii) quality consistency, (iv) delivery time, (v) dependability, (vi) product flexibility and (vii) volume flexibility (derived from Benton, 2014). Interviews with suppliers provides an understanding of supplier perspective of a strategic relationship with JEWELZ, in terms of product development and continuous improvement.

### **3.2 An 'ABC Analysis' of Gemstones**

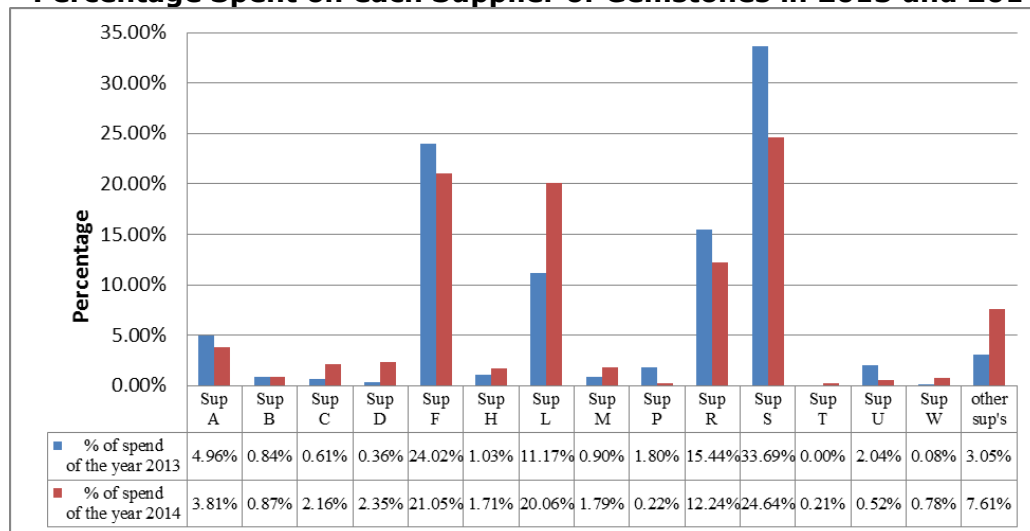
Mangan et al. (2012) describe 'ABC analysis' as a tool to focus on the most important inventory items. It is a tool based on the Pareto principle, that about 80 percent of total purchased value is generated by about 20 percent of all purchased items. JEWELZ has been using 400 items of gemstones which are classified into 4 groups and 7 sub-groups, according to origins and specific production processes.

The ABC analysis revealed that the three most important sub-groups of gemstones are Cubic Zirconia (CZ) normal-white color, CZ treated color, and Colored stones. The accumulated purchased volume of these 3 sub-groups 85% of the total.

### 3.3 Spend Analysis

These gemstones had been purchased from 47 suppliers whose production sites are located in Thailand and overseas. Some suppliers are able to provide more than one sub-group of gemstone, but some sub-groups are limited to a single supplier due to copyright patents or other factors.

**FIGURE 3**  
**Percentage Spent on each Supplier of Gemstones in 2013 and 2014**

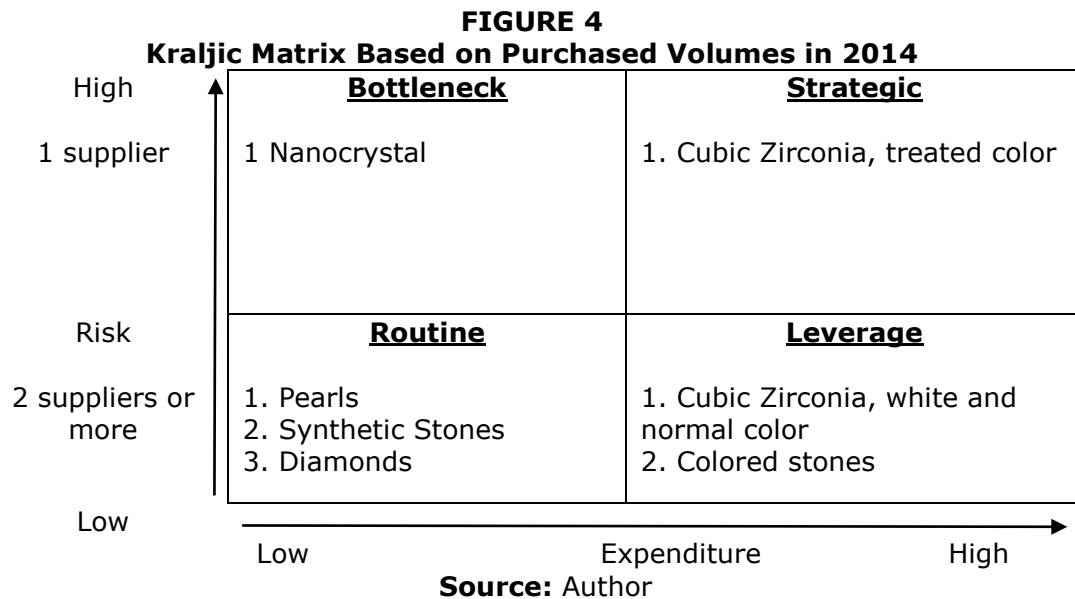


**Source:** JEWELZ database

Cubic Zirconia with treated color and Nanocrystal were provided only by Suppliers S and F. This is a high supply risk. Moreover, Suppliers S, F, L were the top three for amounts spent in 2014 as shown in Figure 4 because they are able to provide various sub-groups of gemstone.

### 3.4 Supply Positioning Model

From these statistics, the Kraljic matrix can be constructed. The bottleneck item is Nanocrystal because only Supplier F offers it (high risk) although its expenditure is not high. The strategic item is Cubic Zirconia with treated color because its high purchase volume of the patented gemstone is available only from Supplier S. The routine items are Pearls, Synthetic stones and Diamonds as their purchased volumes are low, and there are many suppliers available. The leverage items are Cubic Zirconia with white-normal color, and Colored stones as their purchased volumes are high and there are many available suppliers.



The availability of many colors of Nanocrystal, compared with other gemstones, is an advantage that benefits new product development. Thus, although the spend analysis for 2014 indicates that the *Nanocrystal* is a bottleneck item, the researcher should consider the supplier of Nanocrystal as being another *strategic item* (thus amending Figure 4 above).

### 3.5 Gap Finding

In the personal interview, the researcher found that the decision to award purchasing orders to suppliers was based on the personal favor of the buyers. There was no strategic component. As the mission of the Company is to continue being a world class jewelry manufacturer, the buying decision has to be made strategically, and must be transparent and explainable. This does not exist in JEWELZ's traditional buying practice.

Jewelry is a fashion product, subject to regular changes in what is fashionable. The frequency of new collection launches has a big impact on JEWELZ's sales and profit. The creative design function has the major role in constructing a new collections. The suppliers of gemstones have an important role in supporting that creative function, but require some incentives to motivate their cooperation and creative ideas. This is lacking in the current buying practice. This leads to un-awareness of weak performance by suppliers. There is no spur to JEWELZ' continuous improvement of weak suppliers, and is a hindrance to cost efficiency.

## 4 FINDINGS & CONCLUSION

The ABC Analysis determined the most significant gemstones and their four main suppliers. The Supply Positioning Model identified into which of its four quadrants these four suppliers fitted. This model, and the supplier's perception model showed that a close relationship with Supplier S supplying Cubic Zirconia treated color, and Supplier F supplying Nanocrystal, is crucial, since they are supplying the gemstones which are high supply risk and high expenditure.

A Supply Evaluation formula, with its five criteria related each main supplier to an appropriate relationship to JEWELZ. Each of the four main suppliers has strong capacity and different strengths. All compete to gain a bigger share, lowering the price if necessary. Price is not the only criterion for JEWELZ, but rather the added value from innovative designs.

**TABLE 2**  
**Evaluation Scores of the Four Main Suppliers**

<b>Suppliers</b>	<b>Performance Score</b>	<b>Percentage from the Total Score</b>
<b>Supplier S</b>	100	27.10%
<b>Supplier F</b>	103	27.91%
<b>Supplier L</b>	68	18.43%
<b>Supplier D</b>	98	26.56%
<b>Total</b>	<b>369</b>	<b>100.00%</b>

The relationship with important suppliers is proposed, with details, are shown in Table 3.

**TABLE 3**  
**Elements of Relationship with the Four Main Suppliers**

<b>Elements of Relationship</b>	<b>Supplier S</b>	<b>Supplier F</b>	<b>Supplier D</b>	<b>Supplier L</b>
Desired Supplier relationship	Collaborative Relationship		Transactional Relationship	
Information Sharing	Frequent sharing, especially the demand forecast of Cubic Zirconia, treated color (to supplier S) and Nanocrystal (to supplier F)		As much as possible	
Communication	To develop an agreed communication strategy, and plan for regular reviews		As much as possible	
Relevant Strategies	<ul style="list-style-type: none"> <li>- Ensure Supply Continuity</li> <li>- Influence the suppliers</li> </ul>		- Maximize commercial advantage	
Tactics	<ul style="list-style-type: none"> <li>- Process re-engineering</li> <li>- Capture supplier expertise and innovation</li> </ul>		- Maintain competition	
Actions	<ul style="list-style-type: none"> <li>- To work closely with the supplier</li> <li>- Supplier development</li> <li>- Supplier account manager</li> <li>- Contingency planning</li> </ul>		<ul style="list-style-type: none"> <li>- Promote competitive bidding</li> <li>- Spot Purchase</li> </ul>	

**Source:** Author

Suppliers S and F are able to supply gemstones in critical quadrant and leverage quadrant, thus it is highly appropriate for JEWELZ to form collaborative relationships with them. JEWELZ also set up with them a continuous review process as a way of nurturing and refining the new relationship. JEWELZ still needs Suppliers D and L (in the leverage quadrant) to maintain supply competition, but they do not warrant a collaborative relationship.

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## **Session 4: Urban Logistics and Humanitarian Logistics**



# SMART PARKING FOR THE DELIVERY OF GOODS IN URBAN LOGISTICS

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## Abstract

The purpose of this research is to develop an application to reserve slots of loading and unloading activities in urban environment and create a collaborative low cost solution based on BLE (Bluetooth Low Emission) beacons to monitor this process. Violations can be easily detected through a collaborative process among user mobile devices detection and a reward mechanism incentives user participation. This approach allows the implementation of a system to handle parking slots for load and unload of goods, without investments costs using an ad-hoc network of users that sends information to a central system and from this violations were sent to control agents.

This solution allows the coordination of the usage of parking places for load/unload of goods in a city environment following European guidelines. The developed App assists operators towards parking place with routing and traffic advice and collects data for mobility authorities.

## INTRODUCTION

According to the European Commission (MDS, 2012), 8-15% of the flow of traffic in urban areas derives from logistical operations involving the movement of goods. Loading and unloading activities are often performed in spaces that are not dedicated to them, causing disruption in the normal flow of traffic and increase in CO<sub>2</sub> emissions (MDS, 2012). Urban goods movement has these negative effects that can occur due to insufficient space infrastructure, presence of large trucks, inefficient use of land used for off-street and on-street loading/unloading of goods on vehicles. The presence of goods transportation trucks parked outside its proper loading/unloading spaces causes congestion and accessibility problems for other road users, since they act as physical obstruction, and they are also a significant cause of accidents, due to their size, adjustability and on-road loading/unloading operations (Awasthi, 2006). Urban freight movements represent a quite low proportion of the total vehicle kilometres (10% -15%), but is one of the top sources of emissions of air pollutants (16% - 50%, depending on the pollutant) (Dabanc, 2008; Dabanc, 2007). Space reservation creates a need of planning on operators and city life benefits from this because distribution is planned to use the available slots distributed in time. Without this planning there is no proper space for logistics activities and high punishment prices should be implemented to prevent misbehaviours. Cities have large populations that share its space and infrastructure for their daily life and for their mobility and for the mobility of goods. Space is limited, which often causes major problems in providing freight transport services. This can lead to a loss of efficiency of urban freight transport operations. The scientific community already looked at this problem (Allen, 2007) and concluded that there are problems associated with Urban Logistics (UL), such as those related to loading/unloading regulations, fines, lack of unloading space, and handling problems. Also authorities have begun to give a greater importance to urban freight transport measures, which can increase its efficiency and sustainability and the

European Union is aware of the importance of UL and its challenges (several project has been financed in this area under the programs FP7 and H2020). UL has different measurements that can be used to improve the logistics of urban freight transport, and they can be organized according to the following categories: 1) public infrastructure; 2) land use management; 3) access restrictions; 4) traffic management; 5) enforcement and promotion; and 6) sharing approaches (Ferreira, 2017). ICT new tools with IoT (Internet of Things), real time information, mobile devices and data connectivity allow the creation of platform systems that monitor distribution activity integrated in a smart city environment and controls several activities that are occurring at the same time in a whole city. These new systems can provide great efficiency gains in terms of getting data analysed to extract knowledge, integrate information and provide real time guidance towards the optimization of route and process. In spite of this, the efficiency and effectiveness of the urban distribution of goods goes back to the rational use of cargo loading and unloading places in urban centres, as highlighted in the main studies developed by Taniguchi (2002) and Allen (2007). These point out that the type and availability of facilities for loading and unloading operations may impact the total cost of the process.

## **RELATED WORK**

Related work in this field of UL is scarce, possibly because the tests conducted at each location are difficult to extrapolate to other places and difficult to implement because most of them needs to fulfil related laws. Also in this field the Green paper on urban mobility (European Commission, 2007) opens a debate with citizens and all relevant stakeholders and financial incentives to study the problem became available. One outcome was CIVITAS implemented in three phases: CIVITAS I (2002), CIVITAS II (2005) and CIVITAS PLUS (2008) ([www.civitas-initiative.net](http://www.civitas-initiative.net)). There is also STRAIGHTSOL (<http://www.strightsol.eu>) with seven demonstrations about freight initiatives, one of them in Lisbon related with parking for load/unload of goods. This initiative due to missing laws and high investments was stopped. Another project was Short Term Actions to Reorganize Transport of goods (START) (<http://www.start-project.org>). This project approach is based on close collaboration between the municipality, transport companies and local businesses formalized in local freight networks.

Regarding the academic perspective there are several investigations that are focused on urban freight distribution at the European level. A comparative study of nine countries, contrasting the objectives, methodologies and results obtained in each of them was performed by Ambrosini (2004). This non-extensive review shows that in spite of different framework methods and models, similar trends emerge at the economic and environmental levels. Other initiative has been introduced at Reims, France. This is a time restriction scheme that foresees time delivery windows for each delivery vehicle entering the inner-city area (Littiere, 2006). Rules for delivery times were attempted in Maribor, Slovenia (Politic, 2006). Taking into account the costs and benefits of this measure during only the year of 2005, around 1000 violations with the lower value (85€) would be identified and the total benefits would be 85K€. At Aalborg, Denmark, a pilot oriented time deliveries, more efficient deliveries, improved working conditions for freight distributors, and reduced numbers of freight vehicles in the city centre (Mikkelsen, 2012).

Barcelona is an example that cargo transport management measures can bring effective results and improvement to the process. Through the SMILE (Street Management Improvements for Loading / unloading Enforcement) project, it has been identified that 100,000 deliveries are made using the urban road as a place for loading and unloading the goods, requiring 4,000 additional loading and unloading places to accommodate all this operation. For better management, loading and unloading operations were concentrated from 8 to 14 hours, allowing a maximum period of occupation of 30-minutes per space, thus reducing the average space occupation rate. In addition, the intensive inspection removed 12,370 vehicles parked irregularly while loading and unloading.

Some other studies examine urban logistics centres and try to identify the potential for the development of urban consolidation centres (UCCs) that have as their main objective the alleviation of local environmental and traffic concerns in urban areas (Browne, 2005). These more specific studies have been of great help when planning to implement initiatives in Bilbao (Browne, 2005).

Among the management solutions, there was a study in Winchester of the benefits of offering reservation of loading and unloading places in urban areas (McLeod, 2011). The authors concluded that there is an improvement in the access to the researched region, however, they point out as a weak point of the proposal the operators arrival on time for their reservation, which, in the worst case, could cause congestion in the road when this happens.

In addition, as a solution, it is proposed to create urban logistics spaces for the distribution of goods, as investigated by Oliveira (2012), which can reduce the number of cargo vehicles using the roads in search of a parking space. Also Dablan (2009) states that these areas are important in urban centres, as few municipalities create organized truck parking centres.

### LOW COST MONITOR ACTIVITY USING SENSORS

There is a new type of sensor devices that opened several business opportunities in healthcare, sports, beacons, security, monitor and home entertainment industries. This Bluetooth low energy (BLE) is a wireless personal area network technology that once compared to Classic Bluetooth is intended to provide considerably reduced power consumption and cost while maintaining a similar communication range. Also in this context there are beacons of around 3-5 centimetres, a small hardware radio device that broadcasts data over Bluetooth Low Energy (BLE). Typical ranges of the radio signal are up to 20 or 100 meters (60-300 feet) and they are easy to fit in many applications and contexts. Together with this, they are very easy to interact with mobile devices sensors, like GPS, Accelerometers and gyroscopes creating a continuous monitor process since users carry the mobile devices all the time. This generates massive data (big Data) through the process identified as Process 1 in Figure 1.

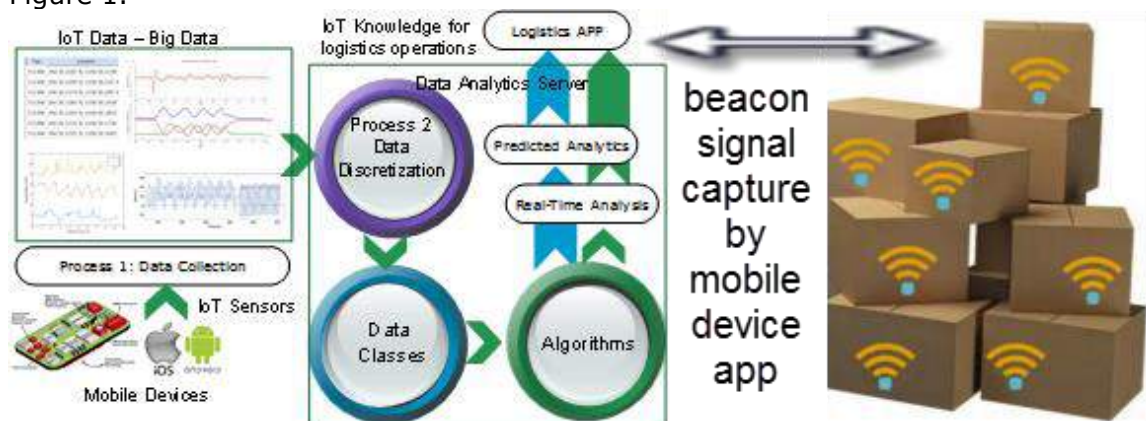


Figure 1. Overview of the proposed system based on sensor data acquisition and manipulation

This collected data can be transformed into information that allows passively tracking the users' mobility or track logistics distribution route process at low cost. Passive tracking of users' activities using mobile devices (Ferreira, 2016) has been assessed in a diversity of studies applied to activity recognition (Turaga, 2008) and transportation mode detection (Reddy, 2010), among others (Patterson, 2003) and our work shows other approach to this in public transportation area (Baeta, 2016). With the Figure 2 we developed an approach for mobile device application. By using it it is possible to track logistics distribution routes and times. Also with the use of beacons at packages it is possible to trace these packages through the interaction of

beacons with mobile devices. Clients can track their packages without big investments because mobile devices capture beacon signal adds position and transmit it to a central system.

To monitor parking activity our proposal is to instal of a beacon in each delivery truck (costs around 3€, with battery life span of 2 years). These requirements should be reinforced by law and each logistics provider should be responsible for its maintenance. This would works like an electronic plate number that allows vehicle identification.

To avoid the creation of infrastructure and networking, our approach is innovative by the usage of citizens and their mobile devices. In this model users get rewards for each beacon signal picked and transmitted to the central parking application. This reward could translate in free parking time and the reward could be increased if an infraction is identified. This reward is based on transmission performed in a price that could be establish as 0,05€.

This process is performed centrally, where the beacon ID is used to check if the truck place was reserved or not. Infraction data can the immediately send to nearest parking agent who would issue the infraction ticket or the central system can send the invoice directly to the logistics operator. Delays to reach reservation slot, or longer times to unload the goods could happened, but they are responsibility of logistic operator.

The reservation system (available in web and mobile interface) sells slots of 15 minutes parking for the identified places, which logistics operator should reserve in advance. The mobile application gives guidance towards parking and alerts of traffic situations. Figure 2 shows the main working idea for the main system with beacon signals captured by mobile devices and truck position is added and transmitted to a central server. This information is proceeded to check if the parking was reserved or not. In order to avoid errors that can result from users receiving beacon signals from a moving truck passing in front of the parking place the system will wait from two notifications of different users before proceeding for infraction identification.



Figure 2. Overview of the proposed approach to create parking monitor facilities without investments costs using an ad-hoc network of user mobile devices in a collaborative process

## LISBON PILOT AND DISCUSSION OF RESULTS

It is clear that there is lack of spaces for freight deliveries in Lisbon and also that there is an abusive occupancy of the available spaces by private vehicles. These lead to road congestion problems and often blockage of roads (when trucks often stop at narrow streets for quick deliveries) and generalisation of illegal parking – such as: freight vehicles parked on sidewalks, double-parking or parked on regular parking spaces, and private cars parked on load/unload parking areas (Andersen, 2012). In spite legislation to regulate loading/unloading activities, there is still lack of rules because most of these places are illegally occupied by vehicles for normal parking. A previous test was performed by EMEL five years ago, but without great results because there was a lack of control mechanisms. To overcome this previous problems, a discussion group was created by a local Portuguese project (Intelligence logistics for urban environments), where several entities studied the problems and advise on change on law to allow an easier implementation of the proposed approach. Each truck receives a beacon that is placed at its cockpit. It is configured with a number that is linked centrally with the corresponding truck. This beacon was configured to transmit signal if the truck is stopped (no movement is detected). This avoid false detection of movement's vehicles. Operators reserve places in times windows with associated prices. These prices (slots of 15 minutes) should be adjusted to avoid a large number of slot reservations that operators might not be using.

To perform a concept proof before real time installation in 2018, we use the 2012 testing street with 10 truck that use this area to distributed goods. Users park the vehicle with beacon and 25 mobile devices of 25 students and professors were used to collect data for a period of 10 weeks. For the testing of the proposed concept, 10 beacon were bought for 30€ (3€/each) and collected 1454 users beacon data transmitted to whom we gave 0,25€ as reward if there is a violation or 0,05€ per transmission. This information allowed identifying 364 infractions (vehicle parked in a different slot from the reserved one), each one leading to a 0,25€ reward to the user. These rewards are used only for parking purposes in the city. This is a small scale pilot was mainly to proof the control mechanism based on this collaborative network of mobile devices. People involved in the test pilot was a mixture of drivers and pedestrian. The pedestrians claim about the energy consumption regarding the App running but always catch beacon signal in their mobile device. Some drivers could not catch beacons because movement process versus short communication range (around 50-70 meters). Data signal transmission at the beacon can be configured, low pooling data transmission means more energy consumption at beacon. From our testing pilot we define a pooling time of 5 seconds. With this rate beacon battery life time decrease to one year.

It is expected that the ITS used allows traffic and CO2 reduction by managing city spaces for load/unload of goods. Travel average times were compared in a month period and a reduction of 5% in peak times was estimated. This process were based on the traffic monitorization without the solution implemented in one month period and compared to one month period of running proposed solution. This monitor process were based on Bluetooth signal capture by 2 master BLE devices installed in the begin and end of the street. With this solution we were able to measure the time that drivers takes to go through the street. Average speed can give an indication of street congestion (Barata, 2014).

### **IMPACTS IN LOGISTICS DISTRIBUTION AND TRAFFIC**

The pilot allowed some preliminary reading from which consequences at different levels can be elaborated: 1) at the level of the service delivery of the logistics companies; 2) at the level of the flow of merchandise and cars in the city; and 3) at the ecological level. These are as follows.

From the perspective of the quality of the logistical service provided by the logistic companies to its costumers it is mostly focussed on on-time and error free deliveries. Being able to keep parking spaces available to pre-scheduled loading and unloading of parcels and general cargo will prevent trucks from having to double line park during their activities and to drive around searching for a parking spot. The extra travel will

reduce on time deliveries and will increase average travelling time, and the double line parking can endanger the physical integrity of the products involved as they will have to overcome additional physical obstacles getting to and from where they should be. Both these aspects contribute to improved logistics service (Grant, 2012).

The ability to park in pre-booked spaces can also have visible impact in the overall flow of traffic in the city. Not only double line parking is prevented, avoiding bottlenecks on the streets, but also the consequent reduction in transit time allows reducing the average number of trucks in the city per period of time. As a consequence all other traffic flows that share the same resources (parking spaces and streets) will be enhanced and will flow more easily. The pre-booked parking policy along with eventual fluctuation of costs for usage at different times of the day will have immediate impacts in the use of capacity available. Although capacity is constant throughout the day demand is not. Price fluctuation for the parking spaces allows transforming the level of demand to be more in line with the level approach of how capacity is made available as it can lead part of the trucks to enter the city at periods of lower traffic intensity (flattening the demand curve for parking spaces). By itself this characteristic will already reduce the flows during traditional heavy traffic hours.

Paying for parking space to load or unload cargo or parcels represents an additional logistic cost for the companies using it. Nonetheless, at the same time it leads to reduction of transit time in the city, reduction of consumption of fuel and reduction of products damaged during the operations. Overall, it can lead a reduction in the overall logistic costs of the operation.

The ecological perspective is very relevant for the Lisbon municipality as recently the city received severe penalty for the intense traffic in some of the roads. Since then the municipality has made large efforts to reduce pollution and improve quality of the air in the city. It is expected from this project that when it goes live there will be a reduction of traffic congestions in the city, therefore lowering CO2 emissions.

Also in our pilot, we perform the testing of goods tracking systems, where goods beacons are captured by mobile devices this devices add GPS position and send this information to a cloud server for processing, see Figure 3 illustration. This can be used for tracking purposes without cost and to sending customers alerts about deliver time. This approach needs to study a reward mechanism for users perform these actions (perhaps money from logistic operator, because we can give client additional services without infrastructure investment costs. The test performed, there was a missing of mobile device through the route path, but when there is a mobile device running the App in background mode the beacon signal is captured and transmitted and tracking it is possible.

## **CONCLUSIONS**

This platform innovated by allowing a pre-reservation policy for a given parking slot in a city and created a low-cost inspection procedure that can be integrated with the different parking space management systems. Violations can be easy detected and data is integrated in mobile devices used by control agents. The usage of this type of ITS in urban areas impact urban mobility globally by allowing operators to react to urban traffic conditions in real time and coordinate their deliveries and consequently reduce road congestion and CO2 emissions.

This system can be financially self-sustained as a pay per use method can be used without installation fee. Considering an average of 100 seats marketed in 30-minute time slots, it is possible to reach about 3000 transactions per day (estimated value of 15 hours per day), or 1,000,000 per year per city. Taking into account an estimate fee of 0,1€/use this gives 100K€ in a year.





Figure 3. Proposed approach to alert customers about delivery process.

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# **COLLABORATION IN URBAN DISTRIBUTION OF FOOD PRODUCTS: INSIGHTS FROM UK ONLINE RETAILING**

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## **Purpose of this paper:**

Population growth, congestion and environmental damage alongside the increased use of convenience stores and the home delivery of items bought online are challenging the traditional methods of logistics. The aim of this paper is to identify collaboration opportunities in the distribution of food in urban areas. We initially investigate the current market structure and operations focusing on food distribution in urban areas and how grocery retailers are fulfilling their online orders by providing new services (home delivery or click and collect services) to their customers. The above pose challenges to the online grocery market in terms of increased operational costs, increased carbon emissions, traffic and noise. Our main objective is to propose sustainable logistics models and to reduce economic, environmental, and social costs whilst maintaining service levels. One way of achieving this is using shared business models which involve collaboration only in the logistics activities, by pooling demand from multiple retailers. This helps reduce the volatility of demand and improve the utilisation of fleet.

## **Design/methodology/approach:**

We test via simulation our logistics sharing models using: i) primary data from UK retailers, ii) secondary data published by exclusive online retailers, and iii) data from a survey about the customer's preferences when they buy groceries online.

## **Findings:**

We show that the reduction could be more than 10% on the total travelled distance based on the model parameters when two retailers collaborate in a centralized model where a single decision maker will solve the operational vehicle routing problem.

## **Value:**

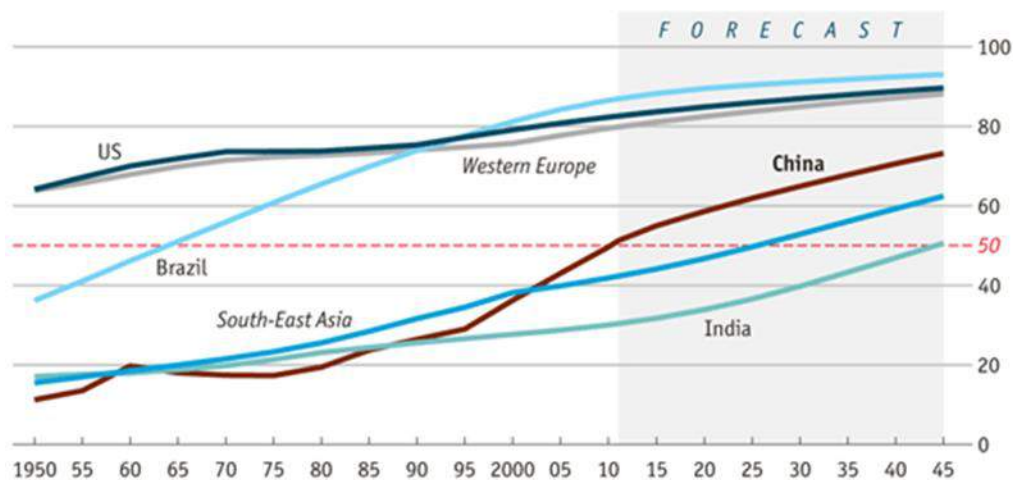
We develop a collaborative model for the grocery market in which there are specific constraints and suggest appropriate incentives that could be incorporated for online retailers to change their independent logistics models to the collaborative one. Moreover, our results are based on real market data.

## **Research limitations/implications:**

We use the existing network of warehouses and distribution centres without proposing any structural changes to the distribution networks of actors involved. Suggestions for future research are: i) to find the best locations for the shared facilities, and ii) to examine the impact of the application of a Collaborative Planning, Forecasting, and Replenishment system in last mile delivery operations.

## 1. Introduction

Urbanisation is now a trend around the world. Figure 1 shows the percentage of population who live in urban areas. For instance, in Europe 75% of the population lives in urban areas and the estimations increase this percentage up to 80% by 2020 (EEA, 2010). Nowadays, more people prefer to live in cities; so, demand for all kind of products is higher in the urban areas. This means that more products need to be transported to and distributed within cities to satisfy people's needs. Urban areas represent specific challenges for freight transport related to economic, environmental, and social aspects (Lindholm and Behrends, 2012). Some of the main challenges are: fuel-distance efficiency, lack of traffic infrastructure capacity, the existing warehouse network and the locations of the physical stores, and how the cities will meet the air quality standards from the European Commission (Directive 2008/50/EC).



**Figure 1** Population as a percentage of total population for US, Western Europe, China, South-East Asia and India from 1950 to 2045, Source: The Economist (2015).

In the global market, a key factor for the competitiveness is the logistics activities, where there are many research works that try to optimise both the organisational and operational logistics practices. It is known that transport is the fastest growing sector with road transport subsector being the largest contributor to the total CO<sub>2</sub> emissions (EPA, 2011). The negative consequences such as pollution and noise are more intense, especially in urban areas. It is common in megacities to have transport-related restrictions such as the size of trucks that can move in the city centre, the hours they could supply the retail shops, etc. Such restrictions make the distribution of goods more complex and raise the total operational and transportation cost, harming the retailer's profitability and increasing the negative consequences on the environment and the society through increased carbon emissions and noise and pollution originating from increased traffic.

During the last years, with the advancement of Internet, a significant proportion of people who live in cities prefer to buy online. This makes a new challenge to the retailers who must provide a non-core service of distribution to end-consumers. In this work, we focus on the grocery retail sector in the UK and especially on the online market. The main reason of selecting this sector is the size (in terms of sales): for example, the European food retail industry is around £1,344 billion and it is expected to reach £1,502 billion by 2019 (MarketLine, 2015). We select the case of the UK, because the online UK grocery market is the second biggest market in the world (in terms of size) after the Chinese online grocery market (IGD, 2016). The sales of the UK online grocery retail market accounted for £8.5 billion in 2015 (Mintel, 2016) and it is estimated to reach £16 billion by 2020 and to be around 10% of the whole grocery market (Mintel, 2016).

There are predictions that highlight that the e-market would dominate the retail sector in the next few years and the online shops would harm the traditional physical shops (Doherty and Ellis-Chadwick, 2010). Moreover, there are evidences for this; for example, the online UK grocery retail market has seen an annual growth of around 17%, while the total grocery market has grown less than 5% annually in the last 10 years (IGD, 2015).

The existing business model in the online UK grocery market is totally competitive, without any kind of collaboration in distribution among the retailers. It is important to note that the four significant retailers possess around 80% of the total online grocery market. In Figure 2 we present the sales for the six leading retailers in the UK during the years 2012-2015. The online retailers in the UK provide two options to their consumers: i) home delivery services and ii) click and collect services. In the first option, the end-consumers select a day and a time slot to receive their grocery orders delivered to their houses, while in the second choice, the retailers transport the consumer's orders to a predefined collection point (known as the click and collect point) where the end-customers must collect their orders during a predefined time interval on the selected day. Both services incur a delivery charge for the end-consumers but for the time being this charge does not cover the additional transportation cost. In the case of home delivery, the additional operational (picking and transportation) cost is £21 (Ocado, 2015).

Retailer	2012	2013	2014	2015
<b>Tesco</b>	£ 2,241	£ 2,635	£ 2,945	£ 3,287
<b>Sainsbury's</b>	£ 1,061	£ 1,180	£ 1,318	£ 1,297
<b>Asda</b>	£ 760	£ 865	£ 1,009	£ 1,038
<b>Waitrose</b>	£ 193	£ 275	£ 377	£ 346
<b>Ocado</b>	£ 732	£ 846	£ 1,009	£ 1,211
<b>Morrisons*</b>	N.A.	N.A.	£ 68	£ 200
<b>Other</b>	£ 686	£ 760	£ 813	£ 1,270
<b>Total of the above</b>	£ 5,673	£ 6,562	£ 7,540	£ 8,649

**Figure 2 Leading online grocery retailers' estimated sales (in million, including VAT), 2012-15, Source: Mintel (2014-2016).**

\* Morrisons started its online grocery service in 2014.

The online UK retailers decide alone how to meet their demand, under the unique objective to maximize their profits. In our case, where the market is competitive this is interpreted as all the retailers have their own fleet of trucks using exclusive distribution centres, under their brand. Therefore, every retailer has to solve an optimisation problem of how to visit the orders' locations of either homes or click and collect points under of course the time preferences of their customers, without considering the global optimal. Retailers use dynamic delivery fee policy associated with these services to alleviate the cost of distribution. However, under this approach the total operational cost is not the optimal (Cachon and Terwiesch, 2006). This happens because customers are free to select any retailer to buy their groceries. Therefore, some neighbourhoods will be visited by many retailers at the same time, because different customers who live nearby will not order from the same retailer. The result is to have overlapping areas during the daily distribution to serve the online customers. These overlapping routings increase the transportation cost, decreasing the capacity utilization of vehicles while negatively affecting the environment and the society through emissions, traffic congestion, accident fatalities, noise pollution, etc.

In this work, we examine the benefits that will arise from a potential collaboration among online retailers to satisfy the demand for home deliveries. Collaboration of retailers in logistics activities does not mean that competition is over as it continues in other aspects of the business. It would be ideal, if all the retailers could work as a single decision

maker and satisfy the demand by using a shared model achieving a centralized solution. The latter is the theoretical ideal situation in terms of cost reduction, but it is almost not feasible to be achieved in a free market such as the online grocery market. Under a shared model, the overlapping routings would be eliminated, increasing the vehicle utilisation and maintain (at least) the existing customer service levels. It is a common approach these kinds of synergies, under which a cost reduction is possible (Forslund, 2015).

## 2. Methodology

We propose a shared logistics model that includes economic, environmental, and social incentives for retailers to work in a collaborative way with their competitors. Delivery distance is analysed in two categories: 1) drop distance which is the distance travelled once a drop or delivery zone is reached, and 2) stem distance, which is the distance to and from a delivery zone. The drop distance remains the same irrespective of the distance from the supplying picking location, but the stem distance varies with the number of picking locations in the system. In this work, we propose a model for using shared vehicles in the stem distance, in which the retailers could use common trucks to transport the orders from their exclusive picking locations which could be stores, dark stores, or dedicated online fulfilment centres to shared hubs in the cities, which are the drop zones according to the above definition. These shared hubs are facilities that all retailers could use for cross docking, but not storage. The mathematical model behind this shared distribution from the picking location to the hub is the vehicle routing problem with pickup and delivery since a large truck will collect online orders picked at each retailer's picking location and deliver to multiple shared hubs. It is assumed that each postcode sector is a drop zone served by a single shared hub. There are 12,381 postcode sectors in the UK, where a postcode sector is 18.78 square kilometres and had 6,979 residents on average in 2011 (ONS, 2011).

We investigate the existing market structure and estimate the following Key Performance Indicators (KPIs): Total travelled distance, Distance per route, Distance per order, maximum number of routes, Stops (shared hubs) per route, Driving time, Driving time per route, Drop-off time, Drop-off time per route, Total time, Total time per route, and Vehicle capacity. Then, we estimate the same KPIs under the proposed shared model in our scenario where two retailers R1 and R2, with comparable market shares to Morrisons and Ocado collaborate in the stem distance from picking locations to the shared hubs in the drop zones. We report the KPIs to quantify the benefits of the collaboration.

An UK-based food retailer has provided us with primary data about its distribution of groceries purchased online for home deliveries. Due to the reasons of confidentiality, the data was aggregated over a year and anonymised. The data set contains 346,745 orders from 533 postcode sectors in London from 01/06/2014 to 31/05/2015. We present the distribution of aggregate consumer demand over time in Figure 3.

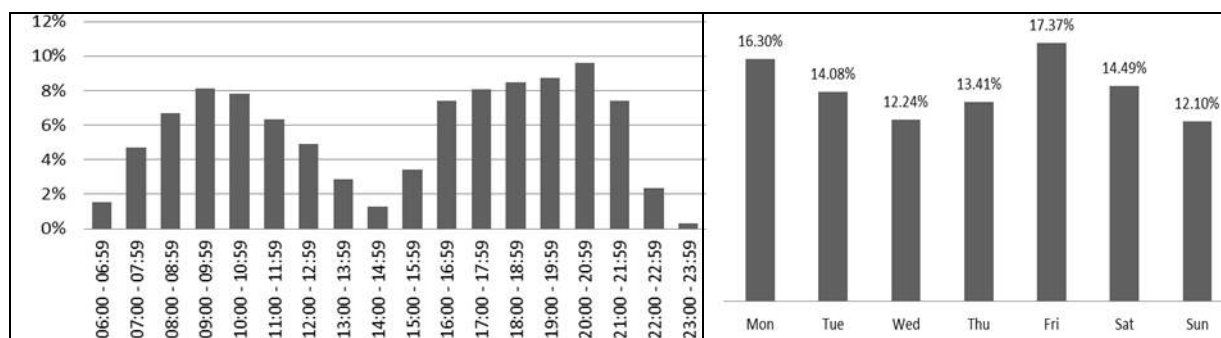


Figure 3 Demand distribution of groceries purchased online, Source: Anonymised Primary Data, 2015.

As a remedy to the lack of sufficient primary data we also developed a survey to elicit the consumers' preferences for buying groceries online in the UK. One of the main objectives of this survey is to examine if there is a pattern in consumers' preferences for delivery days and time slots when they select their orders. Based on our survey of a sample with 2,800 who purchase from many online retailers, it is a realistic assumption to use the demand distribution for our collaboration scenario (Figure 3).

Then, we develop a methodology to generate secondary data to estimate the demand for home deliveries of groceries purchased online for the six major UK retailers (Figure 2), due to a lack of primary data from these major retailers. To evaluate the collaboration in the online grocery market, we use the secondary data to estimate the online grocery demand based on postcode sectors. Therefore, we generate the demand using data from secondary sources such as Ocado (2016) and Mintel (2017). We evaluate the accuracy of our approach (i.e. generation of annual demand for home deliveries) based on a primary data set obtained for the U-TURN project (<http://www.u-turn-project.eu/>). We present the main steps of our home delivery demand data generation methodology for the online grocery market as follows:

1. Establishing the overall UK online grocery market size and individual market shares of the six major retailers.
2. Adjusting online grocery sales according to the geographies served by each retailer and the UK population data.
3. Calculating orders per capita by postcode sector for each retailer.
4. Adjusting the online grocery orders per year by postcode sector by retailer using the retailer's store footprint.
5. Calculating the total number of online grocery orders.
6. Applying a seasonality profile to total online grocery orders per year to derive daily orders (Figure 3).
7. Estimating the demand for six major retailers (Table 2).

### 3. Analysis and results

In this section, we quantify the benefits that arise from collaboration on the logistics activities under the scenario that R1 and R2 will work together in the proposed model of shared vehicles for the stem distance.

Based on the primary data set, we work only with the postcode sectors where the demand is high enough to fit a theoretical probability distribution (at least 30 orders). There are 266 postcode sectors with at least 30 observations (individual postcodes) for which the aggregated number of orders are reported. This means that we continue with 49.9% of the total postcode sectors in the primary data. Then, we test seven theoretical probability distributions (Cauchy, Exponential, Gamma, Logistic, Lognormal, Normal, and Weibull) and assess the goodness of fit. We choose the distribution and the parameters with the minimum Akaike Information Criterion for each postcode sector. We run all our analyses in R using the `fitdistrplus` package. For the 266 postcode sectors, we have estimated the parameters of the theoretical probability distributions. We also run the analyses in MATLAB for a sample (25 out of 266 sectors) of sectors to verify the theoretical distributions that have been fit using the `fitdistrplus` package. We found no instances where the parameters fit by MATLAB were significantly different from the parameters fit by R. The distribution of demand is Lognormal in 96% (256 out of 266) of all postcode sectors, while the demand in the remaining 10 sectors follows the Exponential distribution. For one of the 266 postcode sectors, the ONS does not provide population data, so we exclude this sector from the analysis (for the sake of completeness the postcode sector is 'E20 1'). Therefore, the remaining postcode sectors are 265.

We assess the performance of our demand generation methodology based on secondary data using the weighted Mean Absolute Percentage Error (w-MAPE). The advantage of a

weighted metric is to give more weight to the sectors with larger demand. Making a large error in a small area is not as important as making a small error in a large area which may inflate the number of orders estimated. At the last stage, we determine the values of the two parameters in demand generation methodology: 'Population' and 'Store Mix', steps 3 and 4 to minimize the weighted MAPE. The parameter values tested are given in Table 1. This happens for the equal weight (50% - 50%) between 'Population' and 'Store Mix' where the weighted MAPE is 0.478.

**Table 1 Error measures depending on population and store mix, Source: U-TURN, 2017.**

Population	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Store Mix	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%	0%
MAPE	0.478	0.472	0.478	0.493	0.513	0.54	0.571	0.609	0.652	0.698	0.747
Weighted MAPE	0.527	0.507	0.493	0.484	0.479	0.478	0.482	0.491	0.504	0.52	0.538

Based on these values we generate the annual demand for the online market for Tesco, Sainsbury's, Asda, Waitrose, Ocado, and Morrisons (Table 2 **Error! Reference source not found.**) and based on this demand we continue with the analysis. The outcome of our approach is presented in Table 2 for five postcode sectors in London: 'E10 5', 'E10 6', 'E10 7', 'E1 0', and 'E11 1' (U-TURN, 2017).

**Table 2 Estimated annual online grocery orders per retailer per postcode sector, Source: U-TURN, 2017.**

Postcode Sector	Tesco	Sainsbury's	Asda	Ocado	Waitrose	Morrisons
E10 5	8,299	4,085	2,208	3,593	864	791
E10 6	9,139	4,499	2,432	3,957	951	871
E10 7	6,649	3,273	1,769	2,878	692	634
E1 0	6,182	3,043	1,645	2,676	643	589
E11 1	6,521	3,210	1,735	2,823	679	622

We examine our proposed model under the scenario that two retailers with comparable market share to Morrisons and Ocado collaborate on the logistics activities to meet their online demand. A rough estimation about the number of annual online orders for R1 and R2 is around 13.3M, possessing 16% of the total online market. Both retailers operate two picking locations to serve consumers in London, where our focus is on the 265 postcode sectors. We assume that every sector is served by a single picking location. Under this assumption, Picking Location 1 serves 198 sectors and Picking Location 2 serves 67 sectors. We do not propose any major modifications to retailers' distribution network, since it is too costly for retailers to change their existing distribution network to achieve short term cost savings and emission reduction (Cachon, 2014). We assume that the picking locations are fixed to our problem.

Then, we calculate the following 12 KPIs, when R1 and R2 work independently (the As-Is situation) and when they collaborate (the proposed shared logistics model):

1. The total distance that must be covered,
2. The average distance per route,
3. The average distance per order,
4. The maximum number of routes required to satisfy the demand,
5. The average number of served hubs per route,
6. The total driving time for the whole fleet,
7. The average driving time per route,
8. The total drop-off time for the whole fleet,
9. The average drop-off time per route,
10. The total time (i.e. driving time plus the drop-off time) for the whole fleet,

11. The average time per route,
12. The utilization of fleet at the starting point (i.e. at the picking location).

To calculate the above KPIs, we use the following model parameters: Average Speed (km/h), Time to drop/location (min), Time/order (min), Shift length per route (min), and Loading time per route at picking location (min) as presented in Table 3.

**Table 3 Model parameters.**

Parameters	Values
Average Speed (km/h)	20
Time to drop/location (min)	10
Time/order (min)	2
Shift length per route (min)	480
Loading time per route at picking location (min)	30

Then, we assume that the two retailers collaborate in the stem distance (To-Be situation) and calculate the same KPIs based on the values of model parameters (Table 3). Thus, we measure the benefits from collaboration making comparisons between the KPIs in the As-Is and To-Be situations.

We examine four different vehicle capacities; 10, 15, 20 and 25 orders, for both picking locations. Table 4 presents the summary of benefits that arise from the collaboration for both picking locations. Note that the results are based on the values of the parameters that are shown in Table 4. For all the examined KPIs (except the Vehicle Capacity Utilization) the retailer's collaboration incurs reduction of them.

**Table 4 Benefits when two retailers collaborate with shared vehicles for the stem distance.**

	Picking Location 1				Picking Location 2			
Capacity	C10	C15	C20	C25	C10	C15	C20	C25
Distance (↓)	6.4%	8.6%	10.1%	11.5%	5.5%	5.7%	9.4%	11.7%
Distance/route (↓)	4.0%	5.8%	6.5%	8.8%	4.6%	6.9%	8.4%	10.6%
Distance/order (↓)	6.4%	8.6%	10.1%	11.5%	5.5%	5.7%	9.4%	11.7%
Routes (max) (↓)	3.8%	5.0%	2.9%	7.1%	6.2%	3.4%	0.0%	3.0%
Stops/route (↓)	30.6%	38.7%	41.2%	42.5%	32.7%	42.2%	42.5%	42.6%
Driving Time (↓)	6.4%	8.6%	10.1%	11.5%	5.5%	5.7%	9.4%	11.7%
Driving Time/route (↓)	4.0%	5.8%	6.5%	8.8%	4.6%	6.9%	8.4%	10.6%
Drop-off Time (↓)	16.9%	20.5%	21.8%	22.1%	17.9%	21.6%	22.4%	22.5%
Drop-off Time/route (↓)	14.8%	18.0%	18.6%	19.8%	17.1%	22.6%	21.6%	21.5%
Total Time (↓)	9.5%	12.8%	14.9%	16.2%	9.5%	12.0%	15.3%	17.0%
Total Time/route (↓)	7.1%	9.9%	11.4%	13.5%	8.5%	12.6%	13.9%	15.5%
Vehicle Capacity Utilization (↑)	2.4%	3.0%	3.8%	2.7%	0.8%	-1.1%	1.1%	1.2%

#### 4. Conclusions and discussion

In this work, we considered the UK online grocery market and how the online retailers could improve their operational efficiency in logistics if they work collaboratively with their competitors to satisfy the delivery demand for online grocery orders. The drop density is an important factor affecting the profitability of the home delivery operation, therefore there is a case for collaborating in the logistics of online grocery orders where the areas served have a low drop density.



Our results suggest that it is theoretically possible for the online UK retailers to collaborate in the logistics activities and reduce economic, environmental, and social costs arising from the uncoordinated case. However, implementation of a collaborative model still poses a challenge due to the extremely competitive nature of the food retail market.

Suggestions for future research are: i) to find the best locations for the shared facilities, and ii) to examine the impact of the application of a Collaborative Planning, Forecasting and Replenishment system in their operations.

## ACKNOWLEDGMENTS

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# **A SYSTEMATIC LITERATURE REVIEW OF CHALLENGES IN URBAN LOGISTICS**

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## **ABSTRACT**

### **Purpose of this paper:**

The propose of this paper is a systematic literature review of challenges in urban logistics. This paper reviews existing publications related to challenges in urban logistics in the aspects of private and public stakeholders.

### **Design/methodology/approach:**

The paper presents the results of systematic literature reviews. The first search term identified 1,400 papers related to the topics, but, based on additional criteria's 50 papers are considered as relevant publications. These consist of paper that reviews challenges that related to issues in managerial, engineering techniques and technology as well as stakeholder's engagement in urban logistics.

### **Findings:**

There have been some researches in management challenging public and private stakeholders to collaborate each other before planning and policy making. For technical challenges, there have been researches challenging in two different aspects, one for public stakeholders, involving simulation by employing mathematics, algorithm, and IT for evaluating the proposed plan and policy. For the other, private stakeholders, mathematics and algorithm are as a tool for optimization for the cost. Moreover, there have been attempts to investigate how private and public stakeholders should collaborate each other.

### **Value:**

It is challenge to develop tools for supporting the collaborative between multi-stakeholders such as serious game in order to train employee and other stakeholders in urban logistics.

## **INTRODUCTION**

The urban population is expected to continuously grow by annually by 1.84% (World Health., 2016). Consequently, logistics providers will have to provide quality and reliability of services in areas with high congestion. The main objective of urban logistics is to optimize and organize logistics processes and transportation activities taking different factors into account (Benjelloun & Crainic., 2008). So far, analysis of urban logistics problems has rather focused on managerial, engineering techniques or technical aspects than on activities and interaction between the stakeholders. However, the interactions between stakeholders is key for increasing the efficiency with in complex systems (Rose et al., 2016; Stathopoulos et al., 2012; Österle et al., 2015). Therefore, this article presents the analysis of a systematic literature review focusing on challenges related to collaboration among the stakeholders in urban logistics. The paper consists of four sections, starting with the introduction, followed by the research methodology, before the results are presented and discussed, and ending with conclusion.

## **RESEARCH METHODOLOGY**

The systematic literature review was carried out according to Pickering (2013). It is designed to collect, classify and identify challenges in urban logistics related to stakeholders' interaction and engagement. In-line with Pickering (2013) a review protocol was established before we identified selection criteria, collected and analysed the data. It is followed by a results synthesis, and an evaluation. The main aspects covered in the analysis is on private and public stakeholders, collaborative urban logistics and collaborative technology.

## Keywords and database selection

We used the online databases available at the University of Bremen, comprising Scopus, Web of Science and IEEE and searched for papers from 2007-2017 (present). The main keywords in the first search were 'urban logistics' or 'city logistics' leading to over 1400 hits. Therefore, additional keywords were iteratively added (1. "challenge", 2. "management" and "technical involvement", 3. "management" and "business" and "economic" "engineering" and "computer" and "environment", and 4. "stakeholder" ) till we had three major terms used as filtered criteria. There are "urban logistics with challenges", "management and technical challenges in urban logistics" and "stakeholders in urban logistics".

## Selection Criteria

Since each database defines the subjects slightly differently, we roughly classified the papers in the categories 'technical involvement' and 'management' and applied the following keywords: "management", "business", "economic", "engineering", "computer" and "environment".

## RESULTS

Table 1 shows how many articles identified in each database with the main search terms. 1,425 papers referred to urban logistics and challenges, so further reduction was necessary. We applied the selection criteria mentioned above leading to a reduction of 53 papers.

Table 1 The number of papers obtained in relevant to challenges in urban logistics

<b>Databas e</b>	<b>Main keywords</b>	<b>With "challenge"</b>	<b>With 'Management challenges' and 'Technical challenges'</b>	<b>With "stakeholder"</b>
Scopus	587 2007(16)/2016(107) /2017(8)	174	116	25 2011 (1)/2016 (8)
Web of Science	526 2007(6)/2016 (140) /2017(0)	188	132	12 2009 (1)/2016 (3)
IEEE	312 2007(3)/2016(51) /2017(3)	120	25	16 2011 (3)/2016 (2)

Of the 53 identified papers, 3 of them were replicates, so 50 papers are considered and reviewed (see Table1).

There are not so many on challenges in urban logistics involving stakeholders. These papers are mostly related to planning and policy of collaboration between public and private stakeholders or on models and algorithms related to design and support of stakeholders to pursue the collaborative actions. Most of the papers discussing mathematical models and algorithms were excluded as there are irrelevant. Out of relevant 50 papers, 25 papers regarding to the management aspects whereas 25 involving technic challenges.

## Management challenges related to urban logistics stakeholders

Of the identified 25 papers, there are 6 review papers referring to design and evaluation of policy and planning in urban logistics, 7 papers relating to the simulation of urban logistics models, and the other 12 papers being for urban studies that proposed policy and planning developments. In the research in aspects of management and urban studies, interactions between stakeholders affect the logistics planning. The interaction of stakeholders in urban areas distribution affect the activities in urban systems in two ways: first related to structure and policy sensitives (strategy and planning) and secondly, related to how operators respond to policy innovation (Stathopoulos et al., 2012). Furthermore, regarding freight and logistics topics, the identified studies had a broad scope looking at social, environmental and economic impacts. For interaction between stakeholders in freight operation, it can be stated that early involvement already in the planning of a system (urban space) is essential for the success (Österle et al., 2015). Insufficient interaction between city authorities and private sectors are for example representatives from industries misunderstanding the municipal planning processes (Eidhammer et al., 2016). There are works in analysis of planning and finding methodology (Graham et al., 2015)

### **Technical challenges related to urban logistics stakeholders**

The proposed keywords resulted in 4 papers related to mathematics and algorithms, 6 papers on information technology systems (IT systems) and 14 papers that consider the challenges in simulation scenario of interaction between multi-stakeholders in urban logistics and evaluation the proposed policy. Those were with technological knowledge, such as using mathematics, algorithm, and IT system to apply for optimizing urban logistics schemes, in combining governmental policies and company initiatives.

For the papers on IT systems, recent investigation involved cognitive management framework for Internet of Things (IoT) and how the use of the technology will lead to intelligent and autonomous applications. Many of the papers visualise the effects using simulation models. Furthermore, several papers discuss how IT systems, algorithm and mathematical models can support the decision making process of the stakeholders involved in warehouse distribution, freight flows, routing task, vehicle loading, size and type of vehicles that could enter urban areas, and possible for congestion charges (Cagliano et al., 2014), which again will benefit public stakeholders (van Heeswijk et al., 2016). Collaborative processes and coordination in managerial organizations are supported by IT systems. Algorithm with vehicle routing problem (VRP) showed that the safety stock and the variance of demand influencing total distribution costs and process reliability (Roeder et al., 2016). Another use of VRP refers to optimize possible setting for urban logistics service of a mid-sized town by applying a number of scenarios (Boschetti & Maniezzo., 2015). Agent-based simulation framework provide possibility setting for city logistics service of a town of about 100,000 inhabitants by assessing interaction between five type of autonomous agent (receivers, shippers, carriers, the Urban Consolidation Center operator, and the administrator) (van Heeswijk et al., 2016). The development of City Logistics concepts and related behavioural issues can be made (van Heeswijk et al., 2016). Especially simulations (through agent-based models) have contributed to research concerning the evaluation of stakeholder behaviour and the interaction of different public and private actors concerning different urban logistics and transport measures.

### **Discussion**

The literature review carried out indicates that the investigation for public stakeholders' interest is different from that of private stakeholders, which leads to a mismatching of the policy making process and the operational processes. For public stakeholders, the identified topics concerns management tools increasing the sustainability which also corresponds to what we have identified in the technical papers, describing the algorithms and models behind used for policy planning and assessment. For private stakeholders, the papers are mainly dealing with involvement in the planning process, i.e. interaction with public

stakeholders, but from a micro economic perspective. The technical papers were mostly related to simulation of this interaction or for evaluation of different possible logistics solutions. This review indicates that a holistic approach involving all stakeholders in a system in all phases of a systems life cycle is required, but still difficult to achieve and that there is a need for tools that support effective collaboration between public and private stakeholders. However, to improve the involvement of all stakeholders in policy development and strategic planning processes tools and approaches are available, but the often not implemented due to a lack of understanding of the necessity of stakeholder involvement in all phases.

## CONCLUSION

The literature review shows that there are some works related to managerial issues of public- private interactions for planning urban systems. For the challenges related to technical systems used, we see however that there is little research related to the interaction of private and public systems, which in our view is required in order to improve urban logistics solutions on long term (i.e. either we find papers on traffic management from a public perspective, or we find papers concerning routing optimising from a company perspective, but none on how traffic management systems interact with the route optimisation system etc.). In addition, the focus for private stakeholders is on time and costs, whereas those for public are on sustainability and quality of life for the citizen. Moreover, there have been attempts to investigate how private and public stakeholders should collaborate with each other effectively. There are works looking at how collaboration can be supported. Here we have seen several works on simulation, gamification and participatory design approaches. However, also here the deployment rate seems to be low. We will therefore in the next step focus on the interaction of different IT systems and how to increase the awareness of the necessity of collaboration and stakeholder involvement in all phases.

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# THE INVOLVEMENT OF WHOLESALERS IN A SUSTAINABLE URBAN LOGISTICS: A SURVEY IN THE FRENCH CONTEXT

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## ABSTRACT

For several years, many works have been carried out on urban logistics management, by approaching for example the issue of more sustainable logistics in order to improve the living conditions of city populations. The actors who are traditionally examined are the local Authorities and the logistics service providers, who have implemented urban platforms to reduce the negative impacts of an anarchic development of product flows within the cities. However, very few works have studied the position of wholesalers in a sustainable urban logistics. This is surprising because wholesalers are historical actors of urban deliveries destined for small shops. The aim of this paper, based on a field study carried out in June and July 2016 of 334 wholesalers in the French context, is to examine how wholesalers are doing regarding sustainable practices, and how they have developed an essential expertise that could be useful for local Authorities.

## INTRODUCTION

The wholesaler is usually considered as an intermediary who improves the operation of distribution channels regarding costs and service quality (Rosenbloom & Andras, 2008; de Leeuw et al., 2013). More precisely, it resembles a marketing middleman existing for a sole reason: it can perform one or more marketing and logistics functions, usually by combining the volume of a number of manufacturers and/or retailers more efficiently than themselves (Mallen, 1977). The aim of the intermediation activity is to ease the matching of offer and demand through the linking of several channel members with complementary interests, by taking advantage of both a transactional dimension (organization of trade) and a logistical dimension (management of flows). Hence, the wholesaler exercises a variety of intermediation functions in upstream (production and/or importing activities) and downstream (delivery of convenience stores, restaurants, craftsmen). As synthesized in Table 1, its four main expertises are as follows:

- *The understanding of products and clients.* The central role occupied by the wholesaler guarantees a perfect understanding of products as well as an excellent understanding of clients' needs and expectations. At the heart of the markets, nowadays, trade professionals are an important source of innovation, communication and training, participating in the growth of sales activity.
- *The provision of products.* Received, sorted and stored, the products must then be dispatched on time, in the right quantity, whatever the volume, the diversity and destination. Nowadays, logistics represents an important differentiation factor for wholesalers regarding the competition.
- *The guidance.* The perfect understanding of products, associated to the understanding of the specific needs of each client, guarantees customized recommendations and an optimized contribution of solutions (market studies, technical studies, etc.). In wholesale, relationships are built over time, allowing a permanent adjustment of the services offered.
- *The creation of customized solutions.* Wholesalers create added value to the extent that they provide adapted solutions to each situation. They are capable of making proposals based, in particular, on the development of digitization, to improve customer relationship.

The understanding of wholesalers' practices regarding deliveries in the urban area has not yet given rise to in-depth research in Europe, except for Morganti's research (2011). However, wholesalers are historical operators who, for a century, have been very involved in the supply of small city center shops. The aim of the paper is to present the most recent sustainable urban logistics practices in which wholesalers are associated. A field research was

carried out in the French context in 2016, in several lines of business: food and non-food consumer goods, BtoB capital goods, and the supply as part of the building and public works business. After having underlined the key issues of urban logistics, regarding both public management and management of companies, in particular wholesalers, the main results of field study will be presented before finishing with two evolutions we may foresee in the near future<sup>1</sup>.

**Table 1.** Conventional services of wholesaler

<i>Services to manufacturers</i>	<i>Services to retailers</i>
<ul style="list-style-type: none"> <li>• Information management</li> <li>• Large purchases of goods</li> <li>• Stock keeping</li> <li>• Financial support</li> <li>• Advance orders</li> <li>• Price stabilisation</li> <li>• Link with retailers</li> <li>• Logistical facilities</li> <li>• Marketing support</li> </ul>	<ul style="list-style-type: none"> <li>• Market information</li> <li>• Stock keeping</li> <li>• Financial support</li> <li>• Quick supply of goods</li> <li>• Advantages of specialisation</li> <li>• Control of price changes</li> <li>• Low prices</li> <li>• Trade discounts</li> <li>• Introduction of new products</li> </ul>

## CITY LOGISTICS

The issues linked to urban logistics have progressively appeared over the last twenty years, in relation to the social and urban changes (Taniguchi, 2015). The concentration of people in cities increases each year. This is not necessarily interrelated with the presence of economic activities in urban zones, and in particular in city centers. Indeed, the property pressure often leads economic activities in trade, service and crafts to leave city centers for the periphery. Companies resisting this centrifugal movement are led to re-think their storage methods given the scarcity and costliness of available space: when space is scarce, selling will be preferred over storing, as shown at an early stage by the Japanese case (Jaussaud, 1992). This leads to implementing restocking systems in JIT, and multiplying the transport in smaller quantities. The phenomenon is even more emphasized by the evolution of the consumers' demand, with the ability to access a variety of distribution channels (small shops, large retailers, Internet), and to which the companies offer as large a mix of products as possible, in order to place itself in a very competitive system. Innovation, whether regarding the product or the sales relationship (access to orders, as well as directions for use), further increases the pressure on the activities, and even more in city centers.

Over a long period, the flow of goods was considered as a simple outcome of the economic and social organization; for example, the globalization of markets after World War II was directly at the root of the development of marine containers (Levinson, 2016). Now, the observers of the operation across territories agree on the central role of spatial planning, whatever the geographic scale taken in consideration (Hesse & Rodrigue, 2004). This is notably the case for urban entities as, evidently, the quality of the deliveries completed by wholesalers impact the life of the inhabitants (through the costs and reliability of their servicing), productivity of services (often dependent on a multitude of products). The major role of products in city life is found in a more general manner in all that comes under urban governance as this latter must rationalize flows with the ambition of reducing their negative consequences, maintain the activities that justify the idea of "living together", offer the space necessary to companies, and implement a regulation on deliveries and collection of products (Anderson *et al.*, 2005). Indeed, the capacity of trading in good conditions has become a key element of city productivity and attractiveness, in the sense of "community of actors". Thus, we can say that the dynamic of flow of goods is a good indicator of the vitality of urban areas.

With this general framework, ironically, it has become obvious that we are witnessing a rejection of logistical activities towards the outskirts of cities (Dablanc & Andrianakaja, 2011). Formerly placed in urban areas, the platforms on which the consolidation and distribution of products is done are increasingly moved to the periphery. The same applies to all the

<sup>1</sup> This research has benefited from the financial support of the *Confédération Française du Commerce de Gros et International* (CGI), the French Professional Association of Wholesalers and Intermediaries.

storage sites participating in the regular servicing of dense residential areas, while the frequency of deliveries (or collection), as well as the timeliness constraints, campaign for a positioning at the closest of the barycenter of the zones to supply. This "loosening" is due to two main reasons: (1) the difficulties of logistics professionals to find urban spaces capable of accommodating them in accordance with their priorities (dimension, accessibility, cost); and (2) the people's unwillingness to see the installation of equipment destined to activities that are considered synonymous of deterioration of their environment (essentially as a result of visual and acoustic pollution). Moreover, the negative stances are often relayed by political and administrative decision-makers, leading to an urban planning strongly limited in its installation opportunities.

Consequently, the plans in force to service cities must take into account the loosening and specific constraints of each city. Allen *et al.* (2012) identified 162 studies on road-based urban freight transport activities in 18 countries. They underline the importance of survey techniques as commodity flow, parking location and global positioning system. Numerous plans, in particular those relying on mail transport, are based on the bulk breaking in periphery, followed by a distribution thanks to small delivery vehicles. The result is a multiplication of flows in the cities with crowded access roads because, for example, to replace a 17-ton vehicle, it is usually necessary to have 10 3.5-ton vehicles (Macharis & Melo, 2011). These adverse effects are similar for the exit of products and the waste treatment (Gonzalez-Feliu *et al.*, 2014). Other plans, in particular those of wholesalers, will associate the relative proximity of a storage and flow processing site and the organization of delivery rounds, with small or large vehicles depending on the case. Thus, the bulk breaking is usually combined with value creating activities (advice, service, quality control).

Beyond the functional aspects, the economic (additional charge for activities placed in a dense area) and environmental impacts (increase in CO<sub>2</sub> emissions) weaken the urban system as a whole, becoming increasingly less compatible with a green logistics approach (Taniguchi, 2014). Therefore, it may be useful to seek how to resettle buildings sheltering logistical functions as close as possible to the areas they serve. To do so, a variety of actions are possible. Some actions can be authoritative and resulting from an extremely directive logistical area defining policy: welcoming sites and companies are forced to settle in these areas. Other actions can be based on a very strict regulation regarding the use of infrastructures: for example, traffic can be forbidden at certain times in certain place and for certain types of vehicles, which would mechanically lead companies towards urban logistical areas that will take different forms, according to the needs in terms of frequency of delivery or type of products (Ville *et al.*, 2013).

## **STAKES FOR THE PUBLIC DOMAIN**

The notion of public domain refers to city managers (politicians and technicians) and users (as well as their representatives). The motivation linked to the research of an efficient and sustainable organization of freight distribution can be classified into three complementary domains: environmental dimension (quality of life of inhabitants), economic dimension (general dynamics and ability to attract value creating activities), and functional dimension (smoothness of trade and meeting needs). All these elements are often interconnected together – for example, flows that take place without difficulty generate little nuisance and reinforce the city's attractiveness – and is mostly within the disciplinary field of urban planning:

- *Environmental dimension.* If we consider that the energy balance is an appropriate indicator to measure the effects of the logistical activity on the environment, it must be emphasized that the delivery of products participating in urban transport make up for approximately 30%, and represents 20% of CO<sub>2</sub> emissions (Russo & Comi, 2012). A study carried out in France by the ADEME on the emission of pollutants shows 40% of nitrogen compounds and 45% of small particles, notably linked to diesel engines. This data is directly linked to the people's health and can no longer be ignored by politicians. Overall, the effects of vehicle traffic are noticeable to urban dwellers who are more likely to severely criticize the political choices made where the environment's conservation did not truly belong. However, allocating the entire negative externalities to road freight transport is reductive, to the extent that private vehicles represent 70% of urban traffic.



- *Economic dimension.* On average, the costs of supplying a product represent, for the sole urban area, between 3 and 4% of the product's value. For the shipment of low-priced products, the sum can amount to 10% of the sales price. This proves that wholesalers bear high costs in their urban delivery activity, which makes an efficient organization of logistical activities even more vital. This is especially true as the increase in the delivery costs for their clients leads them to move to the periphery of cities. While many observers agree on the necessity to increase the density of cities while evolving towards a larger diversity of its components, the local Authorities must favor the products' penetration in dense areas; the balance and attractiveness of city centers depend on it.
- *Functional dimension.* A small van parked in front of a small shop, a heavy truck delivering equipment to a construction site, a vehicle collecting waste are all examples of urban life. No one questions this obligation to ensure urban logistics activities, but the inconvenience resulting from it is often recalled (Allègre & Paché, 2014). Also, any ambition of economic development of the city, necessarily leading to a more important freight distribution, must be coupled with measures enabling to meet dispatching needs, or else the general operation of the city would suffer environmentally, as well as economically, as shown by the increase of traffic jams that paralyse a portion of the activity. The challenge is significant, as approximately 20% of the road occupation by motor vehicles is attributable to freight, of which half is linked to the consumers' trips to make their purchases.

## **STAKES FOR THE WHOLESALERS**

While aiming at the same components of the urban system, the professionals' perception is different. Here, the question of competitiveness is a fundamental element to explain their choice in an institutional context, of which they control only a portion of the factors (Lindholm, 2012). This is the case for all wholesalers, whatever their involvement: direct, when making the delivery themselves; indirect, when they charge a service provider with urban logistics operations, totally or partially. In all cases, they are forced by urban-planning choices and the markets to service. The practices cannot be analyzed without taking into consideration the costs, in a context where the time value is constantly present. The extreme diversity of products and types of wholesalers lead to a variety of cases dependent on urban realities (infrastructures, levels of traffic congestion, regulation). However, it is possible to define the main challenges as perceived by the wholesalers, with the same grid as previously adopted:

- *Environmental dimension.* Companies, and in particular wholesalers, taking into account the environmental impacts in their organizational choices, come together today with economic targets, what Hesse (1995) underlined as from the mid 1990s. Companies committed to citizen initiatives, while remaining actors who need to make profits: their survival depending on it. They are aware that the environment increasingly interferes in the competition and some wholesalers develop clearly aggressive tools in that area (use of "clean" vehicles, management of packaging, display of carbon footprint). The tightening of rules defining the acceptable levels of air, or noise, pollution campaigns in favor of the creation of systems enabling a better environmental coordination of urban flows.
- *Economic dimension.* It is the genuine motor of the wholesalers' behavior as their competitiveness is largely related to their aptitude to display an efficient logistics (Rawwas & Iyer, 2013). The quality of dispatch, usually measured in terms of observance of scheduled timetables, as well as the compliance of product quality, is a key element for their development. In this context, the geographical position of platforms from which delivery rounds are organized is prominent. The establishment of urban logistical spaces supposes that the induced bulk breaking does not lead to a significant increase in delivery costs and a deterioration of service quality. It must also take into account the multiple intermediation functions that are performed by the wholesaler (Pardo & Paché, 2015). That is why an intervention of local Authorities is often desired, in an indirect way (support in the use of techniques) or in a direct way (decrease in land price), in order to maintain a low level of rates charged.

- *Functional dimension.* To regulate the trade of products and control time, the presence of urban logistical spaces in dense areas, very close to the city center, can appear necessary. Indeed, transport infrastructures are often congested, in particular at times when the logistical demand is high (between 7 AM and 10 AM), and local Authorities seek to regulate their use by limiting traffic and parking conditions of utility vehicles. According to the configuration of the area to deliver, we will try to get as close as possible to the clients in order to perform the last link with less troublemaking means (by foot, tricycle with electrical assistance, "clean" vehicles) (Thompson, 2015). In other cases, the optimal answer will be, on the contrary, to resort to a vehicle enabling to group several deliveries. In any case, we must imagine differentiated answers, taking into account the living conditions of the inhabitants, judged acceptable by the public players who enact regulations.

## WHOLESALE IN A CONTEXT OF URBAN LOGISTICS

For decades, wholesalers have had an important position in the urban distribution (Dugot, 2000; Pardo & Paché, 2015). Indeed, their professional clients find themselves within the main concentration of economic activities, as well as the concentration of populations and city centers. At the level of France, the activity of wholesalers represents 5 million movements a week, that is to say 4 movements per week and per employee, and approximately 39 movements per week and per facility. If we express this activity in the number of vehicles, there are 58,000 vehicles circulating each day to make deliveries. In the city center, the activity of wholesalers represents approximately 15% of its daily movements (22% in Paris). To know more about the wholesalers' practices regarding sustainable urban logistics, a field study was carried out in France in June and July 2016. The survey was administered by e-mail with the support of the CGI, who relayed the survey over to its members. Several reminders were sent, using its weekly newsletter, or by contacting the federations by telephone. The final sample was composed of 334 companies, distribution of activity as shown in Table 2.

**Table 2.** Structure of the sample

<i>Sectors of respondents</i>	<i>Number of respondents</i>
Food consumer goods	101
Building and public works	91
Non-food consumer goods	58
BtoB capital goods	77
Other	7

The survey carried out shows that 64% of French wholesalers perform over 10% of their deliveries in city centers, and among the latter, 27% perform over 40% of their deliveries in city centers (for 5% of them, over 80% of the activity is concerned). In other words, a majority of wholesalers is confronted, with variable rates, to the issue of delivery in city centers and the stakes of sustainability it implied. This average hides situations very different from one sector to another, and from one company to another. For the food sector, 75% of wholesalers make over 10% of their activity in city centers while wholesalers specialized in inter-industry are only 51% to be concerned by sustainable urban logistics issues. The logistic system of wholesalers is subjected to a triple system of constraints. The wholesaler's ability to integrate answers efficiently, in terms of logistical agility, enables to offer the client a service of high added value:

- *Constraint linked to the products.* The idea is to identify what are the characteristics of the products that will impact the way and the means enabling their transport, storage, distribution and, obviously, to ensure their tracking. The constraints linked to a product can be associated to the product's physical characteristics (weight, volume, density, weakness), the composition of the product (dangerous products, fragrant products), and to the product's conditions of conservation (temperature, hygrometry rate). The survey shows that 73% of the respondents are subjected to constraints linked to the product resulting from the line of business. For the food industry, the temperature constraint is

the most important and it is mentioned in 58% of the cases, while bulky products are mentioned in 59% of the cases for the supply of the building and public works sector. For the inter-industrial sector, the prioritization is less clear, in connection with the variety of products and activities that can be underlined.

- *Constraint linked to the client.* Each client has different demands directly linked to their own logistical organization. It depends on the market's constraints (sales frequency and volume, selection), as well as the physical installation (storage space vs. retail space) and treasury that will push towards a storage rationale or a just-in-time rationale. The client's logistical organization constrains the wholesaler's logistical organization. It essentially has to do with the time and days of delivery, control methods and responsibility over the product, and delays. The client can also ask for additional services, like the return of products and packaging. The main requirements expressed concern the physical delivery (appointment scheduling) and they are reinforced by the monitoring activities and delivery in the customer's presence. This means that, in a majority of cases, the wholesaler can deliver only during time windows when the client is available, that is to say during opening hours. Here also, a nuanced approach is needed depending on their sector. If the time constraint is mentioned in the first place, whatever the business line, its weight on the global system is different between the food sector (25%) and the non-food sector (38%).
- *Constraint linked to the spatial configuration.* In the case of deliveries in the city center, the constraints depending on the city traffic flow, the possibility of stopping and parking, client accessibility, and on the different regulations that govern the city and enable (or forbid) the circulation, parking and delivery of clients. About 20% of the sample feels no limitations. However, several respondents accumulate constraints. The food sector is the most restricted (only 8% of respondents from the food business report no delivery constraints, against 25% for the supply of the building and public works sector). The main issue encountered is the parking, the unloading and traffic of vehicles. Indeed, the delivery zones in town are sometimes used by private vehicles, poorly located (far from the delivery points), too few or badly set up (size does not correspond to the characteristics of certain vehicles, sidewalks or obstacles interfering with the delivery person's route). Furthermore, traffic directly impacts the timeliness *vis-à-vis* the client as well as the transport performance (cost and use of resources). The inter-industrial sector is the most sensitive to traffic constraints (29%), while the non-food sector puts forth handling and unloading constraints (respectively 22% and 16%). Otherwise, a relative homogeneity of the perception of the nature of the constraints can be underlined.

## **WHAT ARE THE FORESEEABLE EVOLUTIONS?**

Regarding sustainable urban logistics, the foreseeable changes in the wholesalers' practices are linked to mutations expected in the two components of the system regulating urban freight distribution: on the one hand, flow management; on the other hand, the organization of the city of the future. These two parties present are nowadays on the eve of deep transformations because of the digital transition of logistics and the ecological transition of the city. The commercial and public stakeholders cannot ignore these evolutions and they must adapt, through a constant dialogue, to the future setting in which they will need to position themselves, as pointed out by the Triple Helix model by Verlinde & Macharis (2016).

### ***Tomorrow's logistics***

Logistics, at the heart of wholesalers' activity, is strongly influenced by new digital tools. The latter are accelerators of flow, information and products, enabling to meet a constantly changing demand, quantitatively as well as qualitatively. The digitization becomes essential to match supply and demand at a time when loyalty to a company is gradually less stable as it is easier to compare the offers and to find alternative answers to needs. This influences the overall process: resources available, financial aspects, available teams and/or providers, stock management, all of which is being coordinated by customer data. The individual, who, previously, was not part of the BtoB relationship, has now become a key player in the global approach of supply chain management of which the wholesalers are only a component. Thus, the digital revolution opened the supply chain upstream and downstream, the globalization

of trade and Internet sales are a few iconic examples. Linked to the digitization, other major changes lie ahead: automation in warehouses, driving assistance software in transport, interconnected city logistics and the physical Internet, the central role of which for a smart city is now mentioned (Zanella *et al.*, 2014; Ben Mohamed *et al.*, 2017). The current evolutions will generate different relationships to space and time because of the multiple interfaces, upon which wholesalers should build.

### **Tomorrow's city**

The regulatory constraint aims at reducing the impact of the traffic and the parking of utility vehicles in the city, and particularly in city centers. They must be designed with a systemic approach, by integrating the interactions of the various players of the system, in particular the interactions between commercial vehicles and private vehicles. Restricting the access of large vehicles to city centers, beyond the physical constraints of access that are widely taken into account by transporters and shippers by favoring "small" vehicles, risks multiplying congestion points. Not taking into account the system of constraints and idealizing some measures risks leading to a construction of partial regulations, with significant risks of adverse effects, regarding the environmental dimension as well the economic dimension. Undoubtedly, this will continue and develop under the pressure of public demand in terms of living conditions. The development of the smart city contributes to this management of logistical operations implemented by the companies supplying the city. Passenger transport, just as product transport, is often perceived as the key challenge of the new sustainable management of public spaces, wholesalers must position themselves as a preferred contact as they are at the crossroads of vital needs of servicing (obligation to provide products essential to craftsmen, businesses and services), political ambitions to revitalize city centers (support and growth of activities and housing), and an increased energetic efficiency (adaptation of the organization of shipments to meet the demand).

### **CONCLUSION**

To please both the public players and the wholesalers, it is essential to engage with these two partners in order to share a common knowledge of the challenges. At a time when urban freight transport is known as a key element of urban policies, while several studies are carried out in the main Western metropolises, the wholesalers' representatives should position themselves as preferred contacts offering satisfactory environmental solutions, as it seems to be the case for the UK's leading food and drinks wholesalers (Jones *et al.*, 2015). Cities expect the involvement of professionals in the testing of innovative organizations capable of improving a situation often deemed troublesome, both on economic and environmental levels. Indeed, several questions remain: what facilities should be developed? What supporting measures should be implemented? What funding is needed? Depending on the cities (size, topography, economy) and nature of products (perishable, bulky, high added value), the solutions will undoubtedly be different, given that the aim is to make the exchanges freer flowing while the demand supported by the transport infrastructures is increasingly significant. Wholesalers represent approximately 20% of the urban freight transport, that is to say approximately as much as the parcel delivery services, for far less nuisances. Indeed, the delivery times, the types of vehicles used, and the optimization of delivery rounds enable a better productivity of the means used and a high creation of value. Therefore, this proves that wholesalers, sometimes perceived as useless intermediaries, participating in an illegitimate increase of the consumer's sales price, could ultimately play a central role in the implementation of a more sustainable urban logistics.

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# THE CITY LOGISTICS-BASED BUSINESS MODEL: A SERIES OF COMPONENTS

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## ABSTRACT

### **Purpose**

City logistics initiatives have been implemented in several European cities, often without the expected success. A major challenge associated with this is the lack of viable business model and the limitation of its components. However, researchers have yet to describe the components of the business model in city logistics as well as to define the city logistics-based business model. In this context, the purpose of this paper is to identify and describe the components of the city logistics-based business model.

### **Design/methodology/approach**

The paper makes a review of Osterwalder's and Pigneur's general business model and city logistics initiatives and identifies the components of the business model related to city logistics. Thus, the components of the business model in city logistics are identified in parallel to the components described by Osterwalder and Pigneur and the current initiatives.

### **Findings**

The analysis led to identify and describe the components of the city logistics-based business model. The study highlights that the business model is a series of components. In addition, the study clarifies the owner and the scope of the business model. All the identified components provide insights into the city logistics-based business model.

### **Research limitations/implications**

The proposed business model can be adopted by public and private authorities to design the business model of a city logistics initiative. A limitation of the study is that it focuses on the 20 most reported initiatives. Another limitation of the study is that it is focused only on European initiatives.

### **Practical implications**

The concept of business model can be implemented in various scopes in city logistics initiatives, and can engage all the sub-business models that are contained in the city logistics system.

### **Original/value**

The research defines the city logistics-based business model and identifies and describes its components.

**Keywords:** city logistics, business model, city logistics-based business model, components, scope, owner, business areas, canvas

## INTRODUCTION

The current rapid urbanization introduces challenges related to the sustainable distribution of goods in the urban areas and city centres (Taniguchi, 2014). It seems increasingly apparent that growing cities depend on efficient and sustainable freight transportation systems. These challenges are related to the rapidly increasing congestion levels on urban roads due to the increasing levels of traffic, emissions and noise as well as safety issues and the liveability and attractiveness of the urban area (Benjelloun et al., 2010; Crainic, 2008). Several cities across Europe have implemented city logistics initiatives, in an effort to address these challenges. However, long-term survival of city logistics initiatives requires a viable business model (Quak et al., 2014).

Understanding the business model in city logistics and its components seems rather limited in current literature. While there is an extensive literature on business models, there is no comprehensive view of how city logistics initiatives should approach their business models. It is broadly addressed in research that the lack of viable business models (Pålsson, 2014, Quak et al., 2014) and the limitation of their components are a barrier to implement city logistics initiatives.

Therefore, the purpose of this paper is to identify and describe the components of the city logistics-based business model, since the business model is a series of components. The paper makes a review of Osterwalder's and Pigneur's (2010) general business model and city logistics initiatives and identifies the critical components of the business model related to city logistics. To this context, the components of the business model in city logistics are identified in parallel to the components described by Osterwalder and Pigneur and the current initiatives (see Figure 1).

The paper is structured as follows. After describing what a business model is, the research approach is presented. This is followed by the results section where the proposed components of the model are presented. Finally, the paper discusses the limitations and implications of the business model and offers a suggestion for future extension of the research.

### What is a business model?

*"A business model describes the rationale of how an organisation creates, delivers and captures values"* (Osterwalder and Pigneur, 2010). Osterwalder and Pigneur (2010) describe the business model as a series of components: the value propositions (product/service offering that create value) (VP), key activities (KA), key resources (KS), key partnerships (KP), channels (value creation, value proposition and delivery) (CH), cost structure (CS), customer relationships (CR), customer segments (CS), and revenue streams (value capture, costs must be subtracted from revenues to create profit) (RS), that cover the four main areas of business: customer, value proposition, infrastructure and financial structure (Osterwalder and Pigneur, 2010).

This definition is sufficiently broad to embrace the different reflections on the city logistics-based business model. Therefore, in this research a city logistics-based business model is a conceptual tool consisting of a series of components and describing how a city logistics initiative creates, delivers and captures values by totally optimizing urban freight transport activities in urban areas, prioritizing stakeholders and their motives in order to express the business logic of a specific initiative.

In this context, it is essential to identify who is the owner as it is a key to the success of the business model and accordingly of the initiatives. The owner uses the model to design the mission of the initiative, define the roles and requirements of the stakeholders, addresses the challenges and define the strategy. Current literature addresses three different stakeholder groups that are commonly described as capable of implementing changes in the initiatives: local governors and administrators; freight carriers; and

receivers (Allen et al., 2015; Cherrett et al., 2012) implying that they could be the owners of the model.

In addition, the scope of the business model is another significant key to the success. When designing a project, the scope needs to be defined in order not to be broad. This will help to keep track of the performances through the project, to discuss and monitor the results. The scope of the business model includes the main objectives of the city logistics initiatives. The most common objectives the initiatives address includes the efforts to reduce the negative environmental impacts (e.g. emissions) as well as increase the safety through a sustainable freight transport system.

## RESEARCH APPROACH

This section discusses how the components of the city logistics-based business model are developed from academic literature and examples in practice. . Methodology to develop the city logistics-based business model (Ci, components) visualises the methodology including two iterative steps: 1. Criteria of selection of the city logistics projects, 2. Categorisation of the selected city logistics projects. Multiple levels of data categorisation and coding were used to triangulate the data. The various sources of data are coded comparably, as suggested by Corbin and Strauss (1990), taking into consideration the criteria for selection presented in the following section.

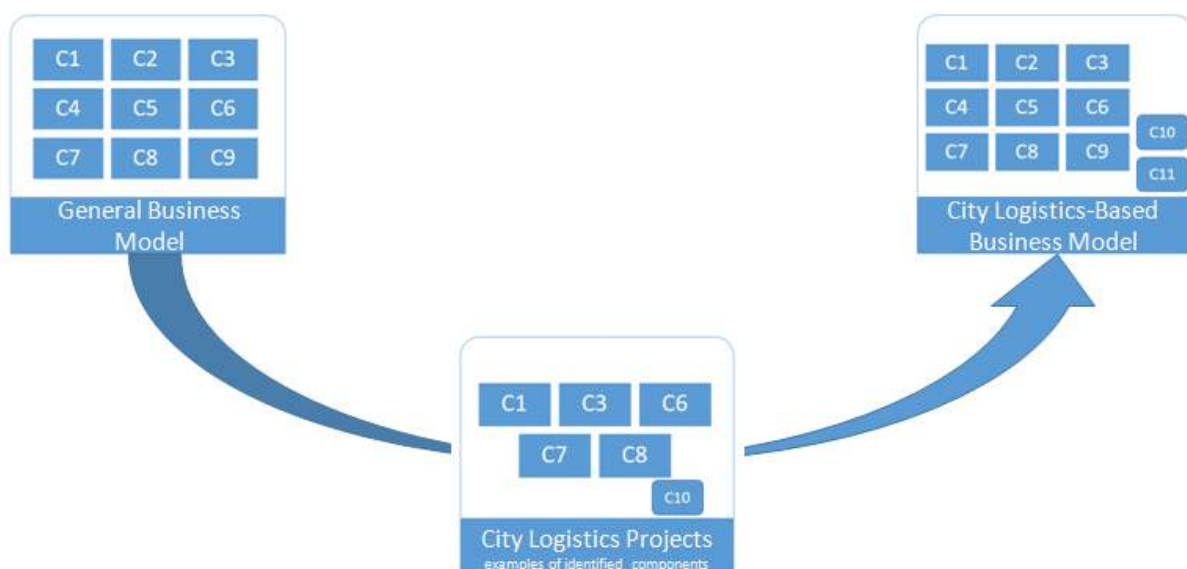


Figure 1. Methodology to develop the city logistics-based business model (Ci, components)

## Criteria for selection of the city logistics projects

Criteria and boundaries were set to facilitate the process of collecting projects during the review. First and foremost, the main criteria of selection of the city logistics projects were:

1. The 20 most reported European projects, within the city logistics literature.
2. Projects that provide exemplars and explain how to implement the general business model.

The selection was used to add structure to literature search, which consists of journal publications in logistics and transports, reports such as BESTUFS, City Ports Project and CIVITAS as well as some further support for details were found on the websites of several of the projects. More subtly, the following academic databases were used for the literature search: Web of Knowledge, Scopus, Emerald and Elsevier Journals. Key words included terms such as city logistics (system), urban freight consolidation centres, business models in city logistics and sustainable urban transport. This literature search generated articles



on city logistics projects (e.g. van Rooijen and Quak, 2008), urban freight consolidation centres (e.g. Browne et al, 2005), sustainable urban transport (e.g. Goldman and Gorham, 2006) and business model in urban areas and city centres (e.g., Macário et al, 2008). Further, major parts of these articles were used to develop the categorization of the selected projects. However, the categorisation was better refined and extended to meet the purposes of this research.

### **Categorisation of the selected city logistics projects**

While some of the selected projects might not directly address the business model in the literature, the identification of some of the components was straightforward. For instance, they showed the value proposition for at least one stakeholder group including the environment and economy. Hence, a deeper categorisation of the projects was introduced in order to address shortcomings of alternative categorisations from the literature. Therefore, there were made four different categorisations. The first one contained the projects from the same country, such as the Netherlands or Germany. The second categorisation consisted of the projects with similarities, e.g. same stakeholder groups or same rules and regulations and even same problems, while the third one consisted of the projects applying the same method for the implementation of their solutions. Finally, the fourth category included the projects with the same components (Table 1).

More subtly, Table 1 shows the selected projects and the components from Osterwalder and Pigneur that were identified in them. To be noted though, all the studied projects have in common their focus on historical city centres, the use of urban consolidation centres (UCC) and the stakeholders. Thus, together with the second categorisation the components of the city logistics-based business model were identified (see results).

<b>Project/ Component</b>	<b>VP</b>	<b>KP</b>	<b>KA</b>	<b>KR</b>	<b>CH</b>	<b>CS</b>	<b>CR</b>	<b>CS</b>	<b>RS</b>
Binnenstadservice (Nijmegen, NL)	X	X	X	X	X	X		X	X
City Cargo (Amsterdam, NL)	X	X	X	X	X	X		X	X
Cargohopper (Utrecht, NL)	X	X	X	X	X	X		X	X
Zero Emission Boat (Utrecht, NL)	X	X	X					X	
Hague (NL)	X	X		X	X	X		X	X
Rotterdam (NL)	X	X	X	X	X	X		X	
Maastricht (NL)	X	X	X						
iLadezone (Vienna, AT)	X	X	X	X				X	X
Consignity (Paris, FR)	X	X	X	X				X	
Monaco UCC (FR)	X	X	X		X	X			X
LaRochelle UCC (FR)	X	X	X	X	X				
Bremen UCC (GE)	X	X	X	X					
Berlin (GE)	X	X	X		X			X	
Kassel (GE)	X	X	X	X				X	
Nurnberg (GE)	X	X	X					X	
Copenhagen (DK)	X	X	X	X	X	X		X	X
Mobile Depot (Brussels, BE)	X	X	X	X	X	X			X
Gnewt Cargo (London, UK)	X	X	X	X				X	X
Bristol city UCC (Bristol, UK)	X	X	X	X				X	X
City Porto (Padova, IT)	X	X	X	X		X		X	X

Table 1: The identified components by Osterwalder and Pigneur on the selected projects

The creation and thus the analysis of crucial categorisations makes use of constant comparisons for similarities and differences, to achieve precision and consistency (Corbin and Strauss, 1990). As part of this process, several rounds of individual coding were created in an effort to understand and support the reasoning behind the categorisations. This process was repeated until saturation was reached on the final categorisation.

A list of eleven components, explained in the results section, was eventually created, after the saturation of the coding and categorisation process.

## **RESULTS**

This section presents the components of the city logistics-based business model, developed in this paper. The components are classified in the business areas by Osterwalder and Pigneur (2010) that describe the business model.

### **Identification of the city logistics-based business model components**

The review shows that most of the researchers use the term business model in order to refer to the way the municipality or the stakeholders, mainly freight carriers, do business within the projects. These researchers utilise the general business model perspective by Osterwalder and Pigneur (2010). Osterwalder and Pigneur (2010) describe the business model as a series of components and that is why the components of the city logistics-based business model are so important.

In all the studied initiatives, most of the described components by Osterwalder and Pigneur (2010) were identified, even when some of the projects did not address the business model directly. However, there are several components that should be listed on city logistics-based business model and therefore, the analysis identified this gap as well as these new components. This identification was done together with the definition of city logistics and the definition of the city logistics-based business model. Hence, some of the components of the general business model were rephrased in order to be representative of city logistics, while some of the new ones were merged together mainly due to their same characteristics. Therefore, the components that should be included in city logistics-based business model are: value propositions (VP), stakeholders (ST), key activities (KA), key resources (KR), logistics bases (UCCs), customer types (CT), customer segments (CS), customer relationships (CR), the value for society (VS) and citizens (VC), financial conditions (FC), policies (P), core competencies (CC).

The components help describing the city logistics-based business model and cover the four main business areas: infrastructure (that includes two sub-categories stakeholders, strategic resources), customer, financial viability and offers. Underlying this practical tool is a detailed conceptual model in which various design variables are considered.

### **Description of the components of city logistics-based business model**

The components and the business areas they belong to are summarized in Figure 2. The components with similar focus or characteristics were grouped under the same areas and sub-categories and an explanation is provided. This led to the creation of the business model in city logistics, which satisfies efficiency (left side of the figure) and value (right side of the figure), as described in the business model canvas by Osterwalder and Pigneur (2010).

More precisely, figure 2 maps the components and provides insights on how the city logistics-based business model should work. The model can be described through its components, which create the categories. Moreover, the figure provides a broad insight on the infrastructure of the business model, which helps also to understand the cost structure. Nevertheless, the figure shows how to map the city logistics-based business model and discuss it even further.

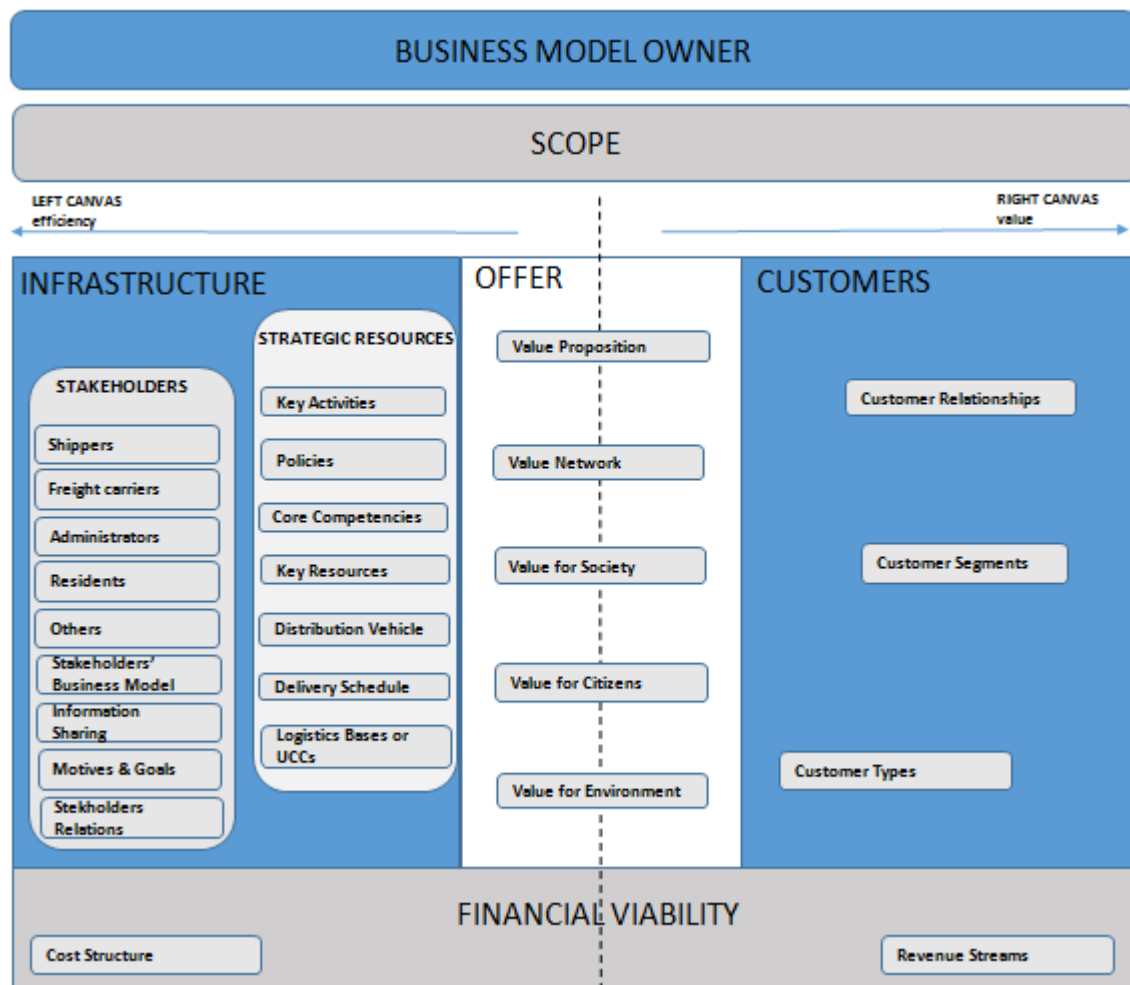


Figure 2. The proposed city logistics-based business model

Infrastructure is the first business area. It is the basic physical and organizational structures and facilities needed for the operation of a project. Thus, this area is divided in two main categories: stakeholders and strategic resources. Stakeholders have a stake or an interest in the outcomes of the actions taken in city logistics. In city logistics, stakeholders are divided into five categories: shippers, freight carriers, administrators, residents and others (Benjelloun et al., 2010; Taniguchi et al., 2001). Therefore, this category not only represents the stakeholders, as a component, but also the separate business models of the individual stakeholders groups. Further, this category represents the information sharing, incentives and the interactions of motives and goals of the involved stakeholders, since the diversity of stakeholders and the heterogeneity of their needs can be a barrier for communication between private and public sector (Taniguchi et al., 2014). The strategic resources incorporates profitable objects that are a key to the accomplishment of the city logistics and enhance a city logistics project's competitive advantage. In general, it describes the rules and regulations of the initiative, the key resources and the strategic assets. Hence, it includes key activities, policies, core competencies channels and logistics bases or UCCs. More subtly, key activities are the actions a project do to operate successfully, policies are used as a mean to reach the project's objectives and the core competence is needed for the sustainable profit growth.

The customer area defines the different groups of organizations (customers) a project aims to reach and serve. Based on the definition of Osetrwalder and Pigneur (2010), in order to better satisfy customers, a project might group them into noticeable segments based on their common needs. However, a project have to decide about which segments

to serve and distinguish the customer relationships it wants to establish with each segment. In addition, a project should define the customer types it wants to attract and serve, such as commercial customers.

The financial viability describes all the financial activities incurred to operate the business model in city logistics. This area describes the financial conditions of a project, such as the cost structure and revenue streams. Cost structure refers to the types and relative proportions of fixed and variable costs that incur in a project and is used as a tool to determine prices. Whereas revenue stream reveals the earning a project makes and includes volatility, predictability, risk and return.

The last business area is the offer and represents the value a project generates. This implies that it includes the value proposition, value network and the value for society, citizens and environment.

## **DISCUSSION AND CONCLUSION**

Although the application of the business model canvas by Osterwalder and Pigneur (2010) provides significant insights, it is argued that the need for conceptual frameworks specifically designed for the city logistics is high (Benjelloun et al., 2010). This should have the ability to represent the business model in a higher level of detail as well as being consolidated and adaptable to other contexts. Hence, the proposed model can be adopted by public and private authorities to design the business model of a city logistics initiative. A potential way to conduct the design session could be to begin with the definition of the scope of the initiative as well as with the owner of the business model. This implies that owner of the business model might not be the owner of the initiative and the other way round. Thus, business models might differ a lot depending on the owner of the business model. Further, the owner and the stakeholders will not only identify their incentives for being involved in the initiative (principal benefits associated to the initiative) but also their reciprocal interactions such as value network and value proposition. Finally, the owner of the business model together with the stakeholders need to focus on the strategic resources required to develop the initiative.

From a theoretical perspective, this study clarifies the business model in city logistics. This study aims at constituting an enhancement from the general business model by Osterwalder and Pigneur (2010) in capturing the components of city logistics-business model and depicting the overall complexity of city logistics initiatives.

From a practical perspective, this study shows that the concept of business model can be implemented in various scopes in city logistics, and can engage all the sub-business models that are contained in the city logistics system. Hence, the importance of the definition of a city logistics-based business model lies on the understanding of what a city logistics-based business model is, its components, the scope and the owner of the business model. This constitutes a foundation of all the strategic decisions of city logistics leading to more successful initiatives and is crucial to achieve a sustainable business model in city logistics. However, in order to achieve sustainable city logistics-based business models, it is necessary to understand what the priorities are to solve in city logistics.

A potential limitation is on the number of the selected projects. Twenty projects were taken into account for the present study. The results were drawn from them. Another limitation of this study is the focus on specific European projects. This implies that a future study could focus on non-European projects in order to see how they can implement the proposed city logistics-based business model.

Future research should apply the proposed business model in a number of city logistics initiatives. Also, future research should apply the model to cases not broadly reported in

literature that still need support in the implementation of the business model or to projects outside Europe. This would confirm the transferability of the city logistics-based business model and would offer a field validation to the model.

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# **LOGISTICS OPTIONS FOR RE-DISTRIBUTED MANUFACTURING IN RESILIENT SUSTAINABLE CITIES – A PILOT STUDY**

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## **ABSTRACT**

Urban resilience has been defined as the capacity of (amongst others) communities and businesses to survive, adapt, and grow when faced with stresses and shocks. Re-distributed Manufacturing (RdM) exploits technologies, systems and strategies to change the economics and organisation of manufacturing (in particular location and scale). A series of studies are being undertaken, in the city of Bristol (population 450,000), into how RdM can contribute to a city's resilience and sustainability. Such as a 'Maker Walk', that examines the manufacturing hidden within urban areas. The objective of this paper is to report a pilot study within Bristol, to determine a range of logistics solutions that have the potential to support re-distributed manufacturing to enhance its resilience. As well as sustainability by helping address Bristol's traffic congestion and pollution problems. This paper proposes three potential logistics business models: 1) A logistics cooperative based around locally located service providers; 2) An urban logistics consolidation network; 3) A public transport integrated logistics service. These solutions could be used by logistics service providers, policy makers and regional government. The models provide guidance as to the interventions that require both private and public sector involvement.

## **INTRODUCTION**

This paper brings together, from the perspective of delivering logistics solutions, the concepts of resilient sustainable cities together with that of Re-distributed Manufacturing (RdM). According to the Rockefeller Foundation's 100 Resilient Cities initiative "Urban resilience is the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience". The UK Engineering and Physical Sciences Research Council (EPSRC) states re-distributed manufacturing involves the exploitation of technologies, systems and strategies to change the economics and organization of manufacturing, particularly in relation to location and scale, with a particular emphasis on more localised manufacturing.

The objective of this pilot study, conducted within Bristol, was to determine a range of logistics solutions that have the potential to support re-distributed manufacturing to enhance its resilience. As well sustainability by helping address Bristol's traffic congestion and pollution problems.

The pilot study focuses on the BS3 area where a Maker Walk had previously been undertaken. The Maker Walk methodology was developed by Mike Lewis and Jude Sherry of Bath University as part of an EPSRC-funded RdM network (RDM|RSC) focused on the impact of RdM on resilience and sustainability in a city setting. One of the motivating aims of the RDM|RSC network was to support examination of the current status of manufacturing activity within a defined geographical area – in this case BS3.

## **LITERATURE REVIEW**

### **Re-distributed Manufacturing**

RdM within the context of the UK EPSRC RdM Networks program, has been defined as technology, systems and strategies that change the economics and organization of manufacturing, particularly in relation to location and scale (Pearson, Noble et al. 2013). Smaller-scale manufacturing has the potential, if applied appropriately with suitable levels of localization, to drastically reduce supply chain costs, improve sustainability and tailor products to the needs of users and consumers.

Such smaller-scale manufacturing has the potential to help tailor products to satisfy the specific needs of consumers differing in terms of geographical location, cultural roots, improve sustainability as well as drive the society towards circular economy (Prendeville, Hartung et al. 2016).

While RdM has the great potential to improve sustainability, currently, very little has been understood on how RdM could help small and medium-sized enterprises (SMEs) for gaining economic benefits due to the constraint of their business model, lack of understanding on customers, limited resource commitment on R&D, marketing and sales, supply chain integration, etc.

## **Resilience**

In their examination of how local economic development Shaw & Newby defined sustainability as "the capacity for continuance more or less indefinitely into the future" (Shaw and Newby 1998). As such it incorporates the many facets of sustainability, economic, environmental, and social etc. Many definitions exist, Bonevac states that there are over 300 definitions in literature, going as far as to say that "Devising criteria and measures of sustainability has become a cottage industry" (Bonevac 2010).

In order to be sustainable the manufacturing sector also needs to have resilience: "the ability of a system to return to its original state or move to a new, more desirable state after being disturbed" (Christopher and Peck 2004). Specifically a firm's vulnerability / capacity to survive and adapt, resist decline and respond to opportunities (Valikangas 2010). Allied to this is the concept of regional resilience which has emerged as a trend that is developing a widespread appeal, in particular when examining how regions have fared during the recent economic crisis (Bristow and Healy 2014).

While the vagueness of the term "resilience" has facilitated innovative multi-disciplinary collaboration, it has also made it difficult to operationalise or to develop generalisable metrics (Meerow, Newell et al. 2016). To overcome this challenge, ARUP has collaborated with the Rockefeller Foundation in order to create the City Resilience Index (Da Silva and Morera 2014). The index was developed through a process of stakeholder consultation across a range of cities globally. The index is intended to serve as a planning and decision-making tool to help guide urban investments toward results that facilitate sustainable urban growth and the well-being of citizens. The hope is that city officials will utilize the tool to identify areas of improvement, systemic weaknesses and opportunities for mitigating risk. Its generalizable format also allows cities to learn from each other.

The index is a holistic articulation of urban resilience premised on the finding that there are 12 universal factors or drivers that contribute to city resilience. What varies is their relative importance. The factors are organized into the four core dimensions (and their goals) of the urban resilience framework (Da Silva and Morera 2014):

- Infrastructure and environment – quality and robustness of the systems that protect, provide and connect citizens
- Leadership and strategy – inclusiveness of governance, involving government, business and civil society, and evidence based decision making
- Health and well-being - ability to meet basic needs of people within a city
- Economy and society – ability of systems to enable urban populations to live peacefully and act collectively

## **METHOD**

An inductive approach to the research is adopted. This initial pilot study limited itself to conducting a STEEPLE analysis of the "BS3" area of Bristol by exploiting data from the aforementioned Maker Walk conducted in the area and secondary sources. The STEEPLE analysis helps assess the factors that influence a target audience and how its constituent members behave. The analysis results are used to guide the creation of the proposed

logistics solutions. These were then analysed using the City Resilience Index (CRI) indicators developed by ARUP and the Rockefeller Foundation.

Viewing the process from a Soft Systems Methodology (SSM) perspective, covers stages one to five of the seven-stage SSM process namely:

1. Enter situation considered problematical
2. Express the problem situation
3. Formulate root definitions of relevant systems of purposeful activity
4. Build conceptual models of the systems named in the root definitions
5. Comparing models with real world situations

### **STEEPLE ANALYSIS**

The purpose of a STEEPLE analysis is to help assess the environmental factors (socio-cultural, technological, economic, ecological, political, legal and ethical) that influence a particular target audience(s) and the way they behave. This study is focused upon the BS3 area within Bristol that was the focus of the Maker Walk study conducted by the RDM|RSC network. When viewed from the SSM perspective this will cover or directly enable SSM stages 1,2 and 3.

Within the context of this work the actors can be considered as follows

- Governmental: covering all levels of government including UK government, the EU/EC, local government (City Council and Mayor of Bristol) and local enterprise partnerships.
- Businesses: within this work the primary concern is the manufacturing sector within the BS3 area. However, business retail and property development are also considered.
- Transport and logistics: covering public transport (road and rail) providers as well as logistics service providers.
- 3rd Sector organisations: organisations such as Community Interest Companies or charities that have an interest or role to play in BS3.
- People: all of the stakeholders in the area such as residents, workers and customers.

### **Social**

Typically residents are well employed, broadly well-educated, mainly between 25-44 years of age, and appear to have young families. That said, there are some pockets of relative deprivation, poor employment and low educational attainment. When examining this from the perspective of manufacturing it appears to be beneficial as the wealth of the area is growing. However, questions can be raised about how accepting people will be of a manufacturing presence in their area. Artisanal businesses such as micro-breweries or furniture makers might be tolerated or even welcomed with open arms. However, industries such as a tannery (which is in fact present within the area) may not be tolerated and a better educated and richer local populace may be better equipped to make their feelings known and grievances acted upon.

Similarly heavy or light –goods vehicle traffic could start to be considered to be a social nuisance creating difficulties for business and manufacturing in the area. In particular those business not trading estates located off arterial routes. Additionally housing developments are planned for areas around industrial estates, as well as the issues raised above, a social demand to live in the area could make industrial areas more enticing for housing development. Negatively impacting on manufacturing but also potentially creating conflict between business and households.

### **Technological**

There are a large number of Technological initiatives (such as 5G and Internet of Things testbeds) taking place in Bristol that companies located in BS3 could potentially take advantage of. Some of the initiatives are currently focused around the BS1 area which on one hand could be positive as if the political will is there it might be possible for BS3 to “piggy-back” on these, on the other they could act as lure for companies based in BS3 especially those wishing to use digital technologies.



Within Bristol there several notable technological developments related to transport and logistics. This includes Bristol being used as a test bed for driverless vehicles (Venturer consortium), as well as the Bristol and Bath freight consolidation centre that aims to reduce the traffic impact of the Cabot Circus and Broadmead shopping areas.

### **Economic**

One of the biggest challenges facing manufacturing companies within the BS3 area is the impact of Brexit. Both in the current uncertainty and the outcome of negotiations between the UK and EU to agree terms of exit. However, an analysis of import/export data from HMRC for 2016 out of those companies contacted by the Maker Walk only four were identified that undertake direct import/export activities, the others are likely to be using intermediaries such as wholesalers.

The cost of doing business could also increase due to inflationary pressures and the business rates revaluation that is occurring in 2017.

However, one economic activity in the area that is of particular interest is that of the Bristol Pound, launched in 2012, which appears to have been successful and suggests that the Bristol area is very supportive of local businesses, something that could be beneficial for the idea of re-distributed manufacturing and its supporting activities.

### **Ecological/environmental**

The idea of congestion charging has been proposed several times within Bristol and this might affect businesses in different sectors and sizes unevenly – some sectors are more dependent on transport than others and smaller businesses might be unable to afford the charge or pass on the costs to their customers. Some sectors might find it easier to pass the charge on to their customers than others. The introduction of a charge may also impact SMEs more than bigger enterprises – they tend to have tighter budget constraints. But SMEs might not only face disadvantages due to tighter financial budgets – they might also face them because they lack scale. Big supermarket chains, like Sainsbury's who have a large retail outlet in BS3, have the ability to consolidate deliveries from different suppliers or switch to night deliveries to avoid paying the charge (whilst potentially upsetting local residents). Local corner shops or small manufacturers are more likely to get frequent deliveries from different sources – and are therefore likely to incur additional expenses when congestion charging is introduced and costs are passed onto them.

One environmental factor that has seen significant change within the BS3 area is that of the volume of light good vehicles using the roads in BS3. Using Department for Transport traffic census data giving the Annualised Average Daily Flow (AADF) traffic levels in BS3 were assessed. Based on data from the five traffic census points within BS3 used for this study car and taxi usage hasn't changed significantly between 2000 and 2015, 90248 and 89739 respectively. However, the use of light goods vehicles has increased by over 7000 (a growth of over 50%), having gone from 13563 to 20837.

The A38 Link road (a major infrastructure projected with BS3) and dedicated priority bus route will mean better access to South Bristol. That could tempt more businesses to set up in the area, which has in the past been considered as a poor relation to the city's northern fringe and its easy access to the ring road and M4 and M5 motorways. The road will pass through Ashton Vale, one of the more deprived areas of BS3 as well as passing close to a cluster of BS3 manufacturing companies.

### **Political**

Bristol City Council also deals with complaints from residents about noise and other pollutants. As the BS3 area becomes more gentrified they may receive complaints about manufacturers based in BS3. As such local politicians and local politics could play a big role in shaping the future of manufacturing in BS3. This is further complicated through the

establishment of the West of England authority that will cover the Bristol City Region and have its own elected mayor.

### **Legal**

When Britain leaves the EU, it is broadly accepted that one of the biggest challenges facing the government will be how to untangle more than 40 years of entwined British and European law. Sorting it all into the desirable and the undesirable could take years, even decades. Even though the government speeding the process up by accepting all EU laws now, before sorting through them all later on. Despite this there will be uncertainty for companies as to the legal framework within which they operate (especially with regards to issues such as Customs Union membership). Companies that operate primarily within the local market may experience minimal changes, but those who export or rely on European workers there will be a period of uncertainty. As previously stated the majority of Maker Walk companies in BS3 are not direct importers or exporters.

### **Ethical**

It can be seen that it's very much in a company's interest to be ethical and behave in a responsible manner. The emerging 'maker community' trend does raise interesting challenges. If at present a maker is operating from their shed or garage and manufacturing on a very small scale what happens if they want or need to expand? Do they try and run a manufacturing business out of domestic property or do they try and work out on an industrial unit. This raises the question of where manufacturing should take place, in business areas or within/next to residential areas. However, small manufacturers have the ability to play a positive role in the community providing employment and services.

### **LOGISTICS MODELS**

Using the STEEPLE study and its analysis as stages 1,2 and 3 of the SSM, the work described here covers the outputs generated SSM stages 4 and 5. Where solutions are developed and compared with real-world models.

#### **Logistics Co-operative**

A recent trend has been the emergence of the shared (or sharing) economy. The shared economy is a socio-economic ecosystem built around the sharing of human, physical and intellectual resources, utilising internet technologies. Such models show promise in assisting the transition toward more sustainable mobility systems (Cohen and Kietzmann 2014). Examples of companies who include Airbnb and Uber have shown themselves to be highly disruptive for traditional industries (Cannon and Summers 2014). In some senses they could be considered to be a form of "co-operative" that utilises internet technologies in order to provide a service. However, a key distinction is that such shared economy businesses explicitly operate on a for profit basis (cf. Uber and Airbnb) for the parent company. There are some concerns that the platforms are being used to circumvent employment regulation, although there are both pro and cons to the model (Aloisi 2015).

As can be seen in the map of logistics service providers (see Figure 1) there is a non-trivial number of logistics companies based in BS3. These will range in size from the likes of Royal Mail (who have a delivery centre in the heart of BS3) to a "man with a van" operation. Some form of co-operative or shared economy model (run for the mutual benefit of the logistics providers) could be used to better utilise the logistics service providers located within the BS3 region in the distribution of goods within the BS3, Bristol City and Bristol City region. There is also the possibility to make use of the Bristol Pound. The cooperative could have the following stakeholders:

- Companies (manufacturers and non-manufacturers)
- Local Logistics Providers (logistics companies based in BS3)
- National Logistics Providers (national and international service providers)
- Bristol City Council (facilitators)
- Royal Mail depot (as universal service obligation provider)
- Bristol Is Open (network service provider)

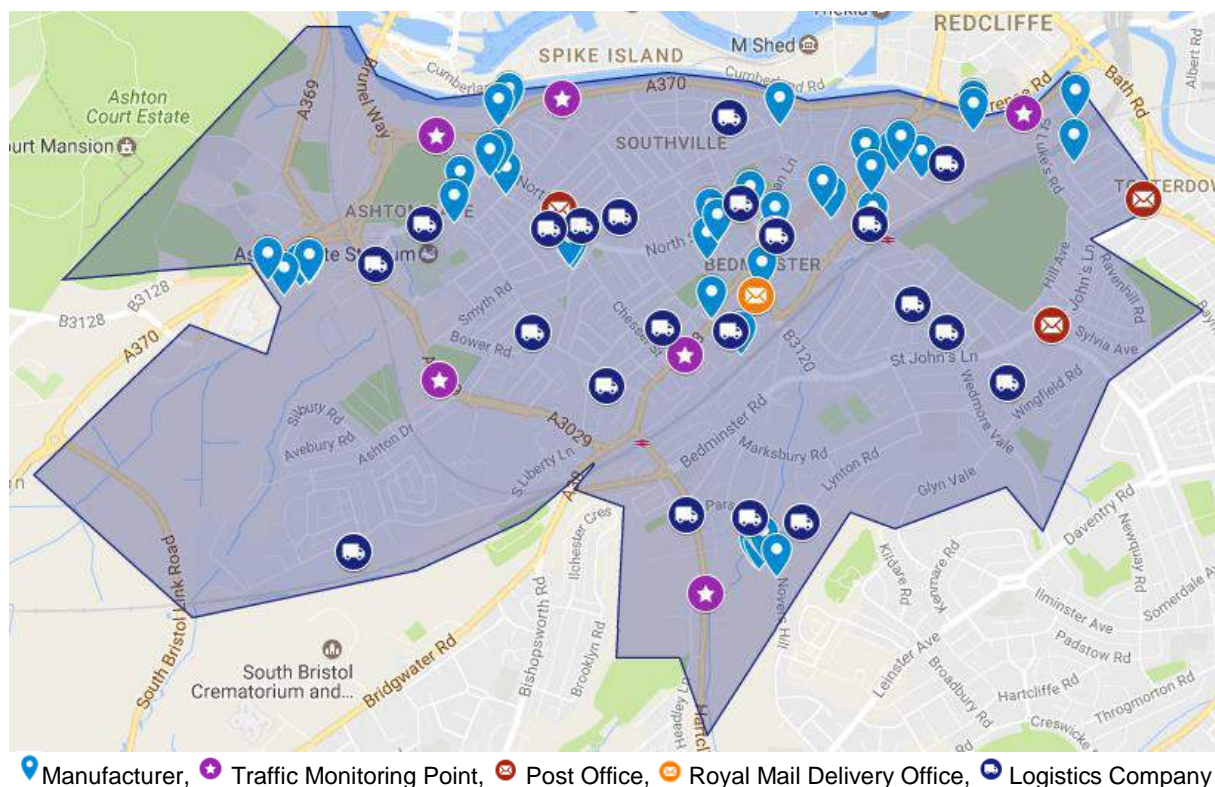


Figure 1: BS3 Maker Walk area indication important locations.

### Urban Logistics Consolidation Network

Urban Consolidation Centres are defined as being a logistics facility situated in relatively close proximity to the geographic area that it serves, to which logistics companies can deliver goods destined for the area (Allen, Browne et al. 2012). They are one of the potential strategies to manage last mile logistics which makes up in the region of one third of urban truck traffic (Dablanc, Giuliano et al. 2013). A study (Ville, Gonzalez-Feliu et al. 2013) has identified that when such urban terminals emerged in the 1990s there were over 100 examples of them, yet at the time of writing there were only 20 genuinely significant terminals of this kind in Europe.

The Bristol and Bath consolidation centre (that within Bristol serves the Broadmead and Cabot Circus shopping centres) has shown itself to be a comparatively rare success story. A study of urban consolidation centres conducted by the SUGAR project (Dablanc, Patier et al. 2011) identified that the lesson learnt from its success is that the use of the centre being of a voluntary nature, so hence only the efficiency of the system encouraged retailers to use it and that it necessary for good operator to run the site. Illustrating that any form of UCC must have a clear benefit for the companies using it.

This model expands on the concept used at the Bristol and Bath Consolidation centre and some of the ideas presented above. It moves away from a centralised hub towards creating a distributed network of consolidation or distribution centres that serve all of Bristol as opposed to just the Broadmead and Cabot Circus shopping area. Where any logistics provider or modality could be used to do the "last mile", including self-service. The service could also be used for the "first mile" enabling manufacturers to drop-off items for future collections. Such centres could reduce traffic and hence noise and air pollution particularly if they are combined with innovative transport solutions, whether it is electric tricycles as in the Petite Reine scheme or electric/hybrid vehicles.

### Public Transport Integrated

Public transport network (in particular buses) provide timetabled intra/inter-town transport services for the general public. This provides the potential to move goods as well as passengers between locations within an area. Internationally there are services that utilise bus networks to deliver parcels. An example of this is the Cargobus service that operates in Estonia which uses intercity bus networks to transport packages both within the country and to other nearby Baltic States.

Using public transport networks, in particular buses, as a method for distributing goods within a city and potentially a City Region. This could potentially deliver smaller items to customers (business and people) who are located near bus routes or with environmentally friendly vehicles making the first and last mile deliveries. Making use of bus lanes and bus only route to expedite the deliveries.

The BS3 area also has two small railway stations on the Bristol Temple Meads to Exeter train line. As such these stations could be used for a railway based parcels service transporting parcels both within Bristol but also to destinations outside of Bristol. There is also a rail freight depot in the western area of BS3 (Ashton Vale area). However, as a heavy freight depot it is geared towards handling containerised loads as opposed to smaller loads that local businesses may require. Additionally freight is configured to be distributed between freight depots which are comparatively few and far between (especially in comparison to railway stations).

## **RESILIENCE EVALUATION**

Of the core dimensions identified by the ARUP and Rockefeller work the proposed logistics business models are most likely to have an impact on economy and society, and infrastructure and environment.

### **Economy and society**

The proposed models through providing novel logistics solutions could help strengthen local economies and systems several ways. By strengthening the business participating in providing the services. Appropriate logistics solutions may make it more palatable for domestic residents to have manufacturers in urban locations enabling a diverse range of businesses to operate through an attractive business environment. Localised logistics provision has the potential to be more flexible and robust, hence contributing to the resilience of the local economy. New models could help develop a strong brand through the 'uniqueness' of the logistics provision within the area, whilst the provision of these models could nurture a stronger economic and business environment.

Currently the models are focused on BS3, but the natural progression would be to expand them to the whole of Bristol. Additionally if expanded into the 'hinterland' then it would be possible to strengthen the logistics integration of the wider Bristol City Region area.

### **Infrastructure and environment**

Whilst not directly linked to codes etc. the use of new logistics models together with city wide planning could help create an environment that is conducive to both people and business. By reducing vehicle movements within area that have problems with NOx and other pollutants could be reduced. The use of congestion charging could be used to actively discourage vehicle use whilst potentially subsidising greener forms of transport (such as green logistics). The use of more environmentally friendly logistics solutions could help protect and enhance the ecosystems of the city. By reducing vehicle movements NOx and other pollutants could be reduced, improving the health of the overall ecosystem.

The use of new logistics models together with city wide planning could help create an environment that makes a more diverse operating environment. Whilst utilising public transport can make better use of road infrastructure, especially when Bristol is already very congested. It also has the potential to subsidise and strengthen the bus network.

## CONCLUSIONS

This work has shown that STEEPLE as part of an SSM approach can be used as a methodology to help enable new logistics business models to be developed. These models when examined from the perspective of resilience using the most appropriate factors from the ARUP / Rockefeller City Resilience Index were all found to have the potential to help improve the resilience of the BS3 area.

## LIMITATIONS AND FUTHER WORK

The main contribution of this pilot study is an initial step towards a more in-depth soft systems approach based study on logistics within resilient sustainable cities. This work focuses an area within a city and thus scalability requires further investigation. Other future work raised by this paper includes: Modelling of environmental impact of solutions; Scheduling, route planning and pricing; Methodology to determine most appropriate consolidation centre locations; Study of delivery patterns for businesses in urban areas.

## ACKNOWLEDGMENTS

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# **AGILITY STRATEGY IN HUMANITARIAN LOGISTICS OPERATIONS: FRAMEWORK AND CASE**

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## **ABSTRACT**

### **PURPOSE**

In humanitarian logistics operations, agility is a strategic response to the typical demand surges in such operations. This study empirically explores agility strategy of humanitarian organizations for the transition process from normal daily operations to emergency relief ones, sometimes called the ramp-up process.

### **DESIGN/METHODOLOGY/APPROACH**

We apply the dynamic capabilities model in strategic management to the context of humanitarian relief operations, and develop three testable propositions to show how these organizations use the agility strategy for effective ramp-up with their existing resources and capabilities. A case study is conducted in six international humanitarian organizations in Indonesia for in-depth contextual knowledge and verification of these propositions.

### **FINDINGS**

The case study shows that the manpower management, prepositioning, and local partner management of a humanitarian organization are related to its current resources and operating context in the ramp-up process. For example, a humanitarian organization with more development programs would rely more on internal staff with ambidextrous capabilities rather than external manpower in this transition.

### **RESEARCH LIMITATIONS/IMPLICATIONS**

The sample size is still small for the generalization of the results. The findings may not be applicable to the other regions in view of the potentially different geopolitical environment. Further empirical study of the topic under different situations may enhance our understanding on the use of the agility strategy in the ramp-up process. Scholars can also explore other aspects of the agility strategy used within and outside of the organization for a better understanding of its agility capability building process.

### **PRACTICAL IMPLICATIONS**

The propositions could be applicable to other HROs in similar environments, and perhaps to commercial enterprises which have limited resources but operating in a volatile environment.

### **ORIGINAL/VALUE OF PAPER**

It would enrich our knowledge on the ramp-up process of an operations and the related agility strategy. Theoretically, the study links the strategic management literature with humanitarian logistics practices.

### **KEYWORDS**

Humanitarian Logistics, Emergency Preparedness, Agility Strategy, Dynamic Capabilities, Case Study



## **Introduction**

For the recent decades, the world has witnessed an increasing impact from natural and manmade disasters (IFRC, 2016). Donors are demanding more accountability and value for money in return for their support of the Humanitarian Relief Organizations (HROs). There is great pressure on the HROs to improve the effectiveness and efficiency of their relief operations (Scholten et al., 2010). As most disasters are characterized by a surge in demand at the onset of a disaster (referred to as the ramp-up process) for supplies and other resources such as manpower, the relief efforts are geared to procuring and delivering goods proactively. This calls for a strategy on the preparation before the onset of an emergency as well as the rapid response thereafter. Agility has become a keyword in the humanitarian logistics literature (Oloruntoba and Kovacs, 2015).

Following the professionalism of the humanitarian relief operations in recent years, many HROs have started to apply commercial supply chain management techniques in their logistics operations; the agility strategy is a key research interest due to the uncertain nature of the humanitarian context (Scholten et al., 2010). However, the complexity and diversity of humanitarian supply chain have so far led to scant knowledge on the appropriate agility strategy for these HROs (Oloruntoba and Kovacs, 2015). Some scholars have taken a theoretical stance to developing comprehensive frameworks (Charles et al., 2010; L'Hermite et al., 2015) but they fell short of the empirical validation. Others have focused on documenting and analysing the current agile practices of the HROs without a sufficient theoretical foundation (Scholten et al., 2010). Our study endeavours to combine the two aspects with a strategic approach by applying the dynamic capabilities model (DCM), a rich theoretical tool in strategic management, to develop a testable framework that explains the approach variety in the practice (Teece and Pisano, 1994; Teece et al., 1997). We propose three propositions based on DCM, and conduct a multiple case study to validate the propositions. The case study is based on a field research of six large international HROs in Indonesia, the largest country in Southeast Asia with over 260 million people. An examination of the context of these HROs and their agility strategies would strengthen the framework significantly and realistically improve the emergency preparedness in many other HROs.

Such a study would also enrich our knowledge of the HROs' transition between emergency relief and normal daily operations, in particular, the ramp-up process when the HROs move from normal operations to emergency response. In doing so, we hope to offer new insights into the ramp-up process, and especially its linkage with the agility strategy of the HROs. The lessons from this study may well be applicable to the other HROs in similar environments, and perhaps to commercial enterprises which have limited resources but operate in a volatile environment.

## **Theoretical Background**

The first activity of a typical emergency humanitarian relief operation is to assess and estimate the supply of goods and services needed, followed by appeal to the donors for funds, mobilizing relief teams for the supply sourcing, in-country receipt and distribution, and coordination with the other HROs (Thomas, 2003). In short, a new supply chain is created, configured, and activated within a few short days in order to respond to the emergency. Whilst the response to every disaster is different in terms of the type of the disaster, the number of people affected and the resources needed, the basic components of a relief operation are quite similar (Tomasini and Van Wassenhove, 2009). Importantly, however, it is already too late to start to develop new solutions after the disaster has struck and the demand for relief has peaked, which normally happens within 72 hours. To respond effectively to an emergency, the HROs must therefore prepare their existing resources with a clearly-defined plan well before the start of such "sudden-onset" emergency, in short, agility capabilities must exist in the HROs.

In today's supply chain, firms need to tackle supply chain risk proactively, ranging from multi-layered suppliers (e.g., tier-2 supplier failures) to customers (e.g., customer needs

modification due to further downward changes) as well as vulnerability along the flow of goods, fund, and information (Tang, 2006). Building an agile supply chain is therefore becoming a key risk-mitigation strategy to prevent any external volatility from disrupting the continuity of the logistics and supply chain flows (Christopher, 2011). It is one of the "triple-A" criteria for top-performing supply chains (Lee, 2004), referred to as the organizational capability to respond rapidly to changes in supply, demand, or market environments. It ranges from operational to strategic levels and demands a supportive culture that fosters cooperation among the entities related to the organization.

In humanitarian logistics, agility or the chain's response to demand surges is critical in emergency relief operations (Oloruntoba and Kovacs, 2015). It has been raised in early studies such as Oloruntoba and Gray (2006), which highlighted the relevance of agility in humanitarian aid operations. Later, Charles et al. (2010) developed a framework to identify the elements of agility as well as the corresponding capabilities to measure the agility of a humanitarian supply chain. However, most of these capabilities are at the operational level such as volume flexibility and velocity. Similarly, Scholten et al. (2010) conducted an explorative study among the HROs and reported the status of the agility practices at the operational level. Recently, L'Hermite et al. (2015) proposed an integrated approach to study agility in humanitarian logistics at the strategic level using DCM, a key strategic management model.

DCM is a core model within the resource-based view, a key management theory on the source of competitive advantage of a firm (Wernerfelt, 1984; Barney, 1991). It focuses on the internal activities of the firm and proposes that firm-specific resources and competencies are critical to superior performance. To yield sustainable competitive advantage, these resources must possess certain characteristics to avoid being imitated or substituted by competitors. DCM is proposed by Pisano and Teece (1994) to explain the means to accumulate such resources and competencies. Dynamic capability is defined as "the ability to integrate, build, and reconfigure internal and external competencies to address rapidly change environments" (Teece et al., 1997:516). It provides a structure to explain the source of competitive advantage by integrating various levels of resources and considering their (re)deployment, (re)configuration, and (re)combination in a changing environment. DCM has proposed three types of capabilities: integration, reconfiguration and transformation, and learning.

Applying the DCM framework on agility capability building in the HROs, L'Hermite et al. (2015) proposed four strategic-level agility capabilities: purposeful, action-focused, collaborative, and learning-oriented. They developed a conceptual model with two agility drivers (risk and complexity, emerging opportunities) and three enablers (people, process, technology). The framework is later empirically examined in a single case study in the World Food Programme, which shows that the strategic-level capabilities are important to supply chain agility (L'Hermite et al., 2016).

Following L'Hermite et al. (2015)'s model albeit with a focus on the emergency preparation strategy by the HROs, we initiate this study to partly answer research questions 6 and 7 in L'Hermite et al. (2015), i.e., how the strategic and supply network levels of an HRO interact to build agility capabilities and how these capabilities create agility for emergency preparation. Thus, we apply DCM to examine how various agility strategies arise for the HROs possessing different capabilities and resources.

### **Theoretical Framework and Propositions**

DCM includes three capabilities: integration, learning, and transformation. For sudden-onset emergency preparedness by the HROs, transformation is very important as an HRO has to quickly mobilize its internal and external resources for any emergency induced demand surge. This mobilization requires significant transformation of its existing resources as adding new resources in such a short period is virtually impossible. Next to transformation, integration is also important as the HRO has to rapidly integrate



its partners for the emergency operation. In DCM, the transformation refers to reconfiguring a firm's asset structure and to accomplish necessary internal and external transformation when the industry environment experiences volatility, while integration refers to the managerial ability to integrate both the internal and external activities of the firm (Teece et al., 1997). In the context of sudden-onset emergencies, the transformation and integration of both internal and external resources of an HRO for relief operations would become the key agility capabilities. We discuss how the agility enablers and capabilities lead to various agility strategies in the ramp-up process.

### *1. Agility enablers*

According to L'Hermite et al. (2015), there exist three agility enablers in an organization: people, process, and technology. We will discuss people and process as technology usage in emergency relief operations is often problematic due to the country status as well as the damage caused by a disaster (Kovacs and Spens, 2009). People includes both internal and external people related to an organization, whose agility is critical for organizational agility. An agile workforce should be experienced, multi-skilled, adaptable, team-oriented, able to handle uncertainty and stress, and be proactive in dealing with threats and opportunities (Sherehiy et al., 2007). In the context of humanitarian logistics, manpower is critical resource but often in short supply due to funding constraints (Kovacs and Spens, 2009). To deal with such shortages, the HROs could adopt a strategy of building both internal and external manpower agility.

Building internal manpower agility refers to enabling relief workers for multiple tasks, both routine development or admin tasks and emergency relief operations. For the HROs with both relief and development programs, they can use the funding for development programs to support staff who are also capable of relief operations. Once a disaster has struck and the call for help arrives, they can quickly move such staff from the development programs to an emergency operation. However, as HROs with fewer development programs are unable to keep sufficient staff internally before an emergency, they would rely more on external manpower sources, either volunteers (often professionals using their own resources for philanthropic work) or local contract workers for short periods of time. Indeed, to make the external manpower work smoothly and quickly with existing staff for emergency operations, an HRO also needs to employ specific strategies to build external manpower agility. It is however beyond the boundary of the HRO and out of our research scope. Thus we posit the first proposition:

**Proposition 1:** *An HRO with more development programs would rely more on internal human capital with multiple capabilities rather than external manpower.*

The second agility enabler is process, which is the way an organization establishes structures and systems to achieve its objective (Sherehiy et al., 2007). In the context of humanitarian operations, it refers to the flexibility of the internal processes to meet emergency needs responsively. Due to the uncertainty surrounding the emergency needs before a disaster strikes, various preparation strategies have been deployed by the HROs. While prepositioning is one key strategy for HROs in emergency preparation (e.g., Mete and Zabinsky, 2010; Campbell and Jones, 2011), practical constraints would limit the HROs' prepositioning capabilities. While it is much more cost effective to preposition supplies and other resources, there are relatively limited financial resources available in advance for a disaster as most resources only flow in after a disaster has occurred (Kovács and Spens, 2009). Further, there is a time lag between the flow of funds and emergency supplies even after the onset of a disaster. One way to overcome these constraints is to leverage on the resources of other existing programs, most of which are development programs with more stable funding and other resources. Thus, for the HROs with regular development programs, the flexibility between their development and relief programs becomes critical. In addition to the manpower flexibility, the funding and supply flexibility is also valuable. One would expect an HRO with both development and relief operations to put much emphasis on the flexibility of

their programs and share their resources as much as possible. Such flexibility would lead to a lower prepositioning volume for the HROs with significant development programs as stated by following proposition.

**Proposition 2:** *An HRO with a significant level of development programs would rely more on its resources in development programs rather than heavily prepositioning supplies for emergency needs.*

## 2. Agility capabilities

In addition to the agility enablers, at a higher level, there are four agility capabilities: builders, being purposeful, action-focused, collaborative, and learning-oriented according to L'Hermite et al. (2015). We focus on the collaborative capabilities which enable an HRO to respond flexibly by collaborating with external partners. Horizontal collaboration among the HROs has been explored in the literature (e.g., Jahre and Jensen, 2010; Akhtar et al., 2012). Here we examine the collaboration between the international HROs and their local partners. According to the DCM framework, an international HRO should be capable of integrating its external partners quickly after the start of an emergency. Such integration cannot happen without the prior time-consuming preparations. Thus, the HROs should invest time and effort to build close relationships with their local partners to make the integration smooth in times of need. Specifically, depending on the international-local HRO dyad by their relative competencies in emergency operations, the HRO could choose a preparation strategy from three scenarios discussed below.

In the first scenario, the international HRO is weak but its local partner is strong in emergency operations. The second scenario is the opposite of the first, the international HRO is strong but its local partner is weak in emergency operations. The third one is when both international HRO and local partner are weak in emergency operations.

Regardless of the emergency relief competency of an international HRO, due to the uncertainty of the location of an incoming disaster, the HRO normally does not have sufficient local knowledge and therefore needs to collaborate with the local government agencies and other local NGOs for an effective operation. In the first case where international HROs can find capable local partners (either NGOs or local governmental agencies) in the region, an international HRO could choose a strategy of outsourcing to maintain its competitive advantage in other aspects such as fund raising. As currently there is no standard knowledge management system in humanitarian logistics in many sites (Tatham and Spens, 2011), outsourcing can reduce the interaction of the two parties and facilitate the integration compared to the scenario of both HROs working in the field. By focusing on advantages like fund raising, the international HRO can also attract local partners for collaboration with its relatively abundant resources. Moreover, given the scarcity of capable local partners, the international HRO would prefer to form an exclusive partnership with the local partner for a stable long-term relationship which may contribute to a smoother integration process when the need arises.

In reality, many local HROs are development-focused and may not be experienced in emergency relief operations (Kovacs et al., 2010). The second scenario is more prevalent, especially for relief operations in developing countries. Moreover, the non-existence of a standard knowledge management system in humanitarian logistics creates more difficulty for HRO collaboration. Under such a scenario, rather than focusing on a few capable partners, the experienced international HROs have to proactively build a broad network with various local partners in different regions. An inclusive rather than an exclusive strategy would work better in this case. They have to take the lead in collaboration and use all means such as workshops and training to contact and connect to groups on the ground, and to build relationships and capacities at the same time. This inclusive approach could include more local NGOs with different specificities, who may collaborate for different tasks. Such training fosters collaboration during emergencies as local partners are familiar with the policies and procedures of the international HROs.

The third scenario is the most challenging one as both sides are weak in the field. Two weak partners are not enough for effective relief works and they have to find a more capable one to collaborate with. This would normally be another international HRO with strong capabilities in the field. Were it a local one, there would be no need to engage another weak local partner. So the solution is three-way collaboration with two international HROs working together, one providing funding and resources while the other managing the work on the ground. In practice, HROs could form a consortium to coordinate their operations in a large disaster-prone country to ensure coverage whilst reducing the effort duplication with a better design of coordination networks (Hossain and Uddin, 2012). Rather than expanding separately in a country, coordination can ensure that each area is covered by at least one HRO with sufficient investment in the local community and network. Thus in any location following the onset of a disaster, the consortium members can participate in relief operations either by themselves or through their HRO partners. Hence, we propose Proposition 3 as follows.

**Proposition 3:** *In collaborating with the local partners, an international HRO weak in relief operations would choose either an exclusive partnership with local partners or collaborate with more capable international HROs by outsourcing; while a stronger HRO would prefer an inclusive partnership with local partners to expand its network in the field.*

### **Research Method and Sample**

As the research on the agility strategy of HROs is scant, we used a qualitative approach of a multi-case study to improve our understanding on their agility strategy. We relied on semi-structured interviews to elicit first-hand information from the humanitarian logistics professionals. This allows the respondents some latitude to share their experience and, at the same time, provides the focus and scope for the discussion. Each interview lasted 45-60 minutes. In addition to the face-to-face interviews, secondary information such as the HRO's archives was examined to supplement the study.

The locus of the study is Indonesia, the largest disaster-prone country in Southeast Asia. The past decades have witnessed disasters such as tsunamis (2004 Indian Ocean tsunami in Aceh), earthquakes (2009 Sumatra earthquake in Padang), volcanic eruptions (2010 Merapi eruption in South Java), and man-made disasters such as ethnic conflicts in the Maluku Islands between 1999 and 2002. Many large international HROs have country or regional offices in Indonesia to support their extensive operations and development programs. It is thus an appropriate location for study.

Moreover, Indonesia has a strong network of local NGOs, numbering tens of thousands, of which 9,000 were officially registered with the Ministry of Home Affairs in 2010 (Figge and Pasandaran, 2011). Many NGOs are heavily involved in humanitarian operations and are HROs as well. Most international HROs operating in Indonesia focus on development programs rather than emergency relief, and only move to emergency operations for a short period (normally a few months) after the onset of a large-scale disaster. Their operations in Indonesia are thus quite different from the activities in other war-torn or famine-struck countries where emergency relief is the main task. Thus, the ramp-up process and agility strategy are important for the HROs in Indonesia.

Eight international HROs with offices in Jakarta were approached, and we visited Jakarta to personally interview the humanitarian logistics staff for the study. Six international HROs (A-F) were willing to be interviewed, whilst the other two were not able to participate as the relevant staff was outstation during the period of our field study. Of the six participating HROs, one is an UN-related global HRO, two are large religious NGOs, and the rest are secular NGOs. All of them are large organizations with recent annual income ranging from US\$200 million to US\$3.7 billion, and operate in many developing countries. All of them are headquartered in the US or Europe, with most of

their income being international donations from the developed countries. All those interviewed were senior logistics staff holding titles such as Director, Senior Officer/Manager, and with many years of field experience in Asia.

## Results

The interview results show that the HROs have used agility strategies for the ramp-up, and largely validate our propositions.

### 1. Manpower preparation

As posited by Proposition 1, HROs with development programs would first move their staff for relief operations. For example, HRO B uses a specialized team for the initial assessment:

*"On manpower needs, we have a National Disaster Management Team (NDMT) with around 40 members in Indonesia. Most of them are based on projects and others are doing admin work in normal times. If a disaster happens, they would be sent to the area for assessment within two days. Some NDMT members would take the logistics responsibilities and make decisions such as demand estimation."*

HRO D and E have similar practices. The Manager of HRO D said,

*"On the human resources for an emergency, we have a specialized team, called the Emergency Response Team (ERT). In normal times, they are assigned to other jobs but they are all trained for emergency operations. We would send some ERT members to the locations for assessment. They will link up with the beneficiaries, and make decisions at the ground such as sending prepositioned goods, ordering more supplies, and engaging trucking companies if needed."*

The Specialist in HRO E gave more details:

*"On manpower, we have an emergency response team, whose members are based on programs but are trained for emergencies. They would do the initial assessment and connect with our networks in the field. Each team would stay in the field for a certain period. If the needs are still there, we may send another team there to rotate the original one. The size of our team is at least three, often with different backgrounds. For large scale emergencies, sometimes we send one team of five members or three teams, each with three members to cover more locations."*

HRO F also rosters its current staff for emergency operations as explained:

*"On manpower for an emergency operation, we have a roster for staff during an emergency so that they would not be over-stretched. We also simplify the recruitment process during an emergency since the contract is only for three to six months."*

The case study supports Proposition 1 as four of the six HROs improve their emergency response by tapping their current resources for manpower needs. This process requires systematically training current staff for multiple tasks. The two HROs not mentioned this approach are either focusing on relief operations (HRO A) or have no-direct involvement in emergencies (HRO C).

### 2. Supply preparation

HRO A, a specialized HRO on relief operations, has adopted a strategy of significant prepositioning as explained by its Manager:

*"We have sufficient prepositioned stocks globally. Funding is an important constraint for us and we have to plan ahead. As it may take three months for us to complete the processing of the dedicated donation and use the funds, we have to allocate sufficient working capital for our supplies in the first three months after the onset of a disaster."*

In comparison, the emergency stock of the other international HROs interviewed is much less than HRO A and their emergency supplies are normally non-food items. Their expectation of the time lag between the onset of a disaster and the arrival of emergency supplies is also much shorter. For example, HRO B typically plans its prepositioned stock for a week's needs. Its Director said:

*"Currently, we have five warehouses in Indonesia for pre-positioning and emergency. We store family kits, children kits, education kits, and etc. The stock should cover one week's supply during an emergency. For example, we have 2500 units of family*

*packages as well as under-five children packages. After getting funding from donors (normally within a week after a disaster), we would deliver more to the beneficiaries. It is difficult for us to store too much due to the cost of the goods as well as warehousing costs."*

HRO E shared a similar concern as HRO B, and according to the Specialist:

*"On the ramp-up process, the first issue is the availability of funds. We and peer HROs such as B and D that focus on child-related programmes have contingency funding, where part of the annual budget is allocated for emergency responses. We have operations in 14 countries in Asia, and nine of them, including Indonesia, are considered as high-risk. Both the country office and its eight field offices have a certain amount of emergency funds."*

HRO D has a similar funding policy according to the Manager:

*"Our emergency funding is from the country finance budget and the programme budget."*

The Director of HRO B provided more explanation on its source of funding:

*"On the funding sources, once an emergency happens, we can use the National Emergency and Preparedness Fund (NEPF) to purchase additional non-food items. Currently the fund is only around US\$1500, quite limited. But it can be used right away without approval from the other offices. The Country Director can approve the usage. In addition, we have a buffer of 20% of the annual development project budget. Each project can use part of its budget for emergency spending. But one restriction is that it can only be used for emergencies in the project area. For emergencies in the other areas, e.g. the 2009 Padang earthquake in Sumatra, we can only use the NEPF."*

As other HROs (B, D, E) are mainly running development programs, and most of funding are, therefore, allocated to these programs, they can maintain a lower level of emergency funding as suggested by Proposition 2.

### *3. Collaboration with local partners*

Local partners are important for the HROs in the task assessment and last mile delivery, but it may be difficult to find suitable ones. As the Manager of HRO A noted that:

*"It is a problem to search for capable partners in some remote areas. Local partners are normally weak on capabilities, and we have to invest and train them. Right partners are difficult to find, we need someone with good scale-up capabilities and who have the local knowledge for last mile delivery. Local governments are important in this aspect as well."*

HRO C, specializing in children programs, uses exclusive local partners in the field. Its Manager explained the rationale:

*"To reach children in many remote areas, we have sixteen dedicated local HROs to support children under our programs. These are long-term partnerships and they are not allowed to work with the other international HROs. With generous funding, the local HROs are willing to have such partnerships, and we would train them for capacity improvement. While we normally do not participate in emergency responses, we will get involved if children we supported are affected by the disaster. We would then contact these children and provide necessary aid to them through our local partners."*

It supports Proposition 3 as HRO C is weak in relief operations. The other HROs with their strong capabilities are less exclusive in their local partners, as the Manager of HRO D explained:

*"Most of our programs need cooperation from partners, governments, and local communities at the village level. They are not implemented alone as we need partners to continue the program after our exit in a few years."*

Clearly the existence of a good relationship with the local HROs and government agencies in the implementation of development programs leads to smoother collaboration in emergency operations. HRO E gave further insight into the process of partnership building and, according to the Specialist:

*"It is hard to find good partners, but we have to do the work before the disaster. Just like the suppliers, you have to identify local HROs in high-risk areas as potential partners for emergency operations whose local knowledge and contacts are of great*

*value to us. Before the disaster, we have training and workshops for the local HROs as our contribution to the partnership. We regularly conduct programs such as Disaster Reduction Programs at the village level with the local HROs and community organizations, for both training and socialisation purposes. Our partners have to be educated on our value and policies and so we can work smoothly during an emergency. They are normally short of funding for such programs, and thus are interested in the partnership as well. We don't want to spend time on such things during an emergency when they can be done at the preparation stage."*

HRO F went further by allowing the local partners to manage its inventory. The Officer explained:

*"Currently we have eight local partners to take care of our emergency stocks, which are the leftover goods from previous disasters. They will update us on the stock every three months, and we are able to respond to small-scale emergencies with our stock. We also have some staff training, as well as training for local partners. Recently, we had an internship program to train one person from our partners for a month in Jakarta on all logistics operations. Last time, we even had some financial support to our local partners as a benefit of managing our stock, but now we no longer provide that funding."*

Vertical partnerships with the local HROs aside, several international HROs also use their horizontal partnerships with the other international HROs to support their emergency responses as posited by Proposition 3. The Director of HRO B explained:

*"When a disaster happens in areas without our presence, we need to collaborate with the other international HROs. For example, during the Maluku flood, as we don't have any projects there but decided to respond to the emergency, we sent non-food items to victims through our partners such as HRO D to help indirectly."*

## **Conclusion**

This paper applies DCM to explore the transition process of the HROs from their normal routine operations to emergency relief. We develop propositions to show how the HROs use agility as a strategy for effective ramp-up using their resources and capabilities. The HROs with more development programs would rely more on internal resources such as development funding and manpower, and demand less supply prepositioning and external manpower. Moreover, in collaborating with the local partners, the international HROs with strong capability in relief operations tend to form more inclusive partnerships while the weaker HROs lean towards exclusivity with capable local partners.

Our findings may help other HROs, especially those running both emergency and development programs. Instead of just focusing on development programs, the HROs could plan ahead to use their resources for potential emergency needs. They could train their staff as well as the local HRO partners with the necessary knowledge and skills for emergency operations. Knowledge such as HRO policies and procedures for relief operations, and skills such as demand estimation after a disaster are valuable for emergency relief activities. Rather than specialization, ambidexterity in both relief and development operations could be the direction of an HRO's human capital development.

This study is the first to investigate the agility strategy in the context of humanitarian logistics, which links the strategic management literature with the humanitarian logistics practice. Further empirical study of this topic in other geopolitical contexts may improve our understanding of the agility strategy in the ramp-up process.

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# **FACTORS AFFECTING THE PERFORMANCE OF HUMANITARIAN LOGISTICS IN EGYPT**

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## **Abstract**

### **Purpose of this paper:**

Humanitarian logistics is critical during disasters, crises and emergency cases, to prevent loss of lives and property. The aim of HL is to alleviate the suffering of vulnerable people during disasters and crises by transporting people or supply the reliefs. The number of people affected by disasters with negative consequences for humans, has risen to get global attention. Developing countries, and their most vulnerable populations, are especially at risk. Therefore, the main objective of the study is to address factors that affect the performance of humanitarian logistics activities in response, recovery phases in Egypt. These factors are financial resource, human resource & institutional learning, use of information technology, collaboration and communication, government situational factors, adequate donors funding, socio-economic situational factors and environmental and infrastructure situational factors.

### **Design/methodology/approach:**

This research is mixed between descriptive and explanatory research. It describe the factors that affect the performance of humanitarian logistics and explain to what extend these factors have impact on the HL performance. The research had applied the deductive approach (quantitative) using a questionnaire survey. The population for this research is the Egyptian business experts engaged in humanitarian logistics in local and international humanitarian in Egypt. The researcher used a convenience sampling technique of 80 Egyptian experts of being engaged in human logistics activities in Alexandria, Egypt.

### **Findings:**

The research revealed that professional staff and institutional learning is the most important factor among the internal factors that showed statistically significant associated with humanitarian logistics activities. However, infrastructure and environmental situational factors is the most important factor among the external factors showed statistically significant associated with humanitarian logistics activities

### **Value:**

The value of this study is to fill the gap in previous and relevant practitioners' studies through addressing the different factors that affect the logistics humanitarian performance in response and recovery phases. In the last several years, most publications have focussed on strategic decision making, humanitarian logistics models, criterial success factors and challenges. Despite of those contributions of the existing literature reviews, the need for more studies into the disaster recovery phase and the need for closer relationships between academia and humanitarian organizations to generate more applied research.

### **Research limitations/implications (if applicable):**

The study opens new opportunities for researchers for further investigation for conducting comparative study targeting corporate sectors, development projects and specific emergencies in other geographical areas.

### **Practical implications (if applicable):**

This study is a useful guidance for humanitarian organization managers and all stakeholders to concern with those factors to avoid any delays to transport and supply reliefs. This is done by addressing and highlighting the factors that effect on the humanitarian logistics in response and recovery phases.

## INTRODUCTION

Global disasters with negative consequences for humans have been increasing in diversity and severity for the past decades. Over 22,000 mass disasters had occurred in the world from 1900 to the present day (CRED, 2017). According to the Centre for Research on the Epidemiology of Disasters (CRED), 371 disasters triggered by natural hazards (DTNH) and 203 triggered by technological hazards (DTTH) were reported worldwide in 2015. DTNH are divided into six sub-groups of natural hazard triggers: Biological, Geophysical, Climatological, Hydrological, Meteorological disasters and Extra-terrestrial. Whereas, DTTH remained unchanged and comprise three groups of hazard triggers: Industrial, Transport, and Miscellaneous (World Disasters Report, 2016).

In 2015, the number of people reported affected by DTTH was the third highest of the decade, while, in contrast, the number of people reported affected by DTNH was the second lowest of the decade. DTNH cost US\$ 70.3 billion, the third lowest amount of the decade, which is 50 per cent below the decade's annual average. For instance, the earthquakes in Nepal cost US\$ 5.2 billion, while 22 other DTNH (10 storms, 7 floods, 3 droughts and 2 wild fires) cost between US\$ 1.0 to US\$ 4.2 billion for a total of almost US\$ 39 billion. All these DTNH accounted for 62 per cent of the total reported damages. The only DTTH for which estimated damages are actually available is the shipwreck of a passenger ship in the Yangtze River, which cost US\$ 15 million. Developing countries, and their most vulnerable populations, are especially at risk. While natural disasters cannot be prevented, much can be done to reduce their human and economic costs in response and recovery phases.

This increase in the number of disasters globally has created complex and multiparty disaster relief operations, that associated with challenges such as lack of accurate information, lack of resources and funding, accountability coordination and communications issues. To mitigate the impact of such disasters, humanitarian relief organizations (HROs), governments, the military, aid agencies, donors, non-governmental organizations (NGOs), and private sector companies—among which logistics service providers across the world are busy rescuing and helping people in disaster-prone areas where the poor infrastructure often makes humanitarian logistics critical to prevent loss of lives and property. According to Thomas and Mizushima (2005) Humanitarian logistics is the process of planning, implementing, and controlling the efficient, cost-effective flow, and storage of goods and materials as well as related information, from source to consumption so as to meet the end beneficiary's needs. Thomas and Kopczak (2005) defined humanitarian logistics as *"the process of planning, implementing and controlling the efficient, cost-effective flow and storage of goods and materials, as well as related information, from the point of origin to the point of consumption for the purpose of alleviating the suffering of vulnerable people. The function encompasses a range of activities, including preparedness, planning, procurement, transport, warehousing, tracking and tracing, and customs clearance"*.

The aim of HL is to alleviate the suffering of vulnerable people during disasters and crises by transporting people or supply the reliefs. Disaster management is often described as a process composed of several stages: Mitigation; Preparation; Response and recovery. These four phases constitute the disaster management cycle. With the focus on logistics, the process that involves logisticians mainly concerns the preparation, response and recovery; together these constitute humanitarian logistics stream (Kunz and Reiner, 2012). The importance of the logistics activity appears in these stages to restore in the shortest time possible the basic services and delivery of goods to the highest possible number of beneficiaries.

With regard to humanitarian logistics stream, it is interesting that the transition between the stages involves the shift in focus from speed to cost reduction in terms of operational performance. However, financial resources, organization personnel, equipment/infrastructure, transportation mode, information technology/communication systems are factors can affect the performance of humanitarian logistics in terms of delays, delivering right quantity of goods and services in right places KINYUA (2013).



While natural disasters cannot be prevented, much can be done to reduce their human and economic costs in response and recovery phases using effective and efficient humanitarian logistics processes. However, there are several factors can affect the performance of humanitarian logistics processes. Therefore, the main objective of the study is to address factors that affect the performance of humanitarian logistics in response, recovery phases in Egypt.

## **LITERATURE REVIEW**

For this study, the researcher focused on the literature that addressed the factors affecting the humanitarian logistics performance and the key indicators are used to measure the performance. The researchers reviewed articles that appeared from the year 2010 to 2017 in international scientific journals (particular Journal of Humanitarian logistics and Supply chain Management) available in electronic databases such as Elsevier's, Science Direct, Emerald Publishers, Springer, IEEE, Taylor and Francis, and Google Scholar. Also, the reviewed literature included several empirical studies from both developed and developing nations such as Kenya, Ethiopia and Indonesia to identify the factors.

Performance measurement is the process to quantify the efficiency and effectiveness of an operation (Beamon and Balcik, 2008). It is a key step to identify corrective actions and the opportunities for improvement that are needed to achieve the aims of HL operations. Many authors (De Brito et al. (2009), Schulz and Heigh (2009), Beamon and Blacik (2008), and Blecken et al., (2009)) declared that performance of humanitarian logistics can be measured by customer service, financial, process adherence, donation-to-delivery time, resources and flexibility.

Most recent study has done by Lu et al. (2016), the authors identified a set of 26 KPIs to measure and monitor HL operations performance by proposing a SCOR framework. The key performance indicators included quality, time, and cost in humanitarian supply chains, and can assist the HROs to measure their performance on agility, responsiveness, reliability, and cost effectiveness. HROs are able to use those KPIs to benchmark both internally against its previous performance and externally with the other HROs, and set realistic targets for ongoing improvement. However, there is a question here: what are the factors affect this performance?

Many authors declared the factors affect HL performance in their studies. Maewski et.al (2010) stated that there are complicating factors such as technology, climate change, shortage of well-trained logistics professionals, transport infrastructure, communication networks, the availability of fuel, and the existence of original capabilities, the lack of coordination and collaboration among various actors involved in humanitarian assistance continues to limit the efficiency and effectiveness of humanitarian logistics. In the same year, Chandes & Pache (2010) highlighted that lack of coordination affects performance of humanitarian logistics operations.

Nolz et. al (2011) highlighted in their study for assessing risks for delivering disaster relief supplies, infrastructure may disrupt the delivery of relief aid. Kunz and Reiner (2012) identified two categories of factors: internal organizations that very prevalent to the organization itself and can be affected or intervened or improved and external situational factors that cannot be changed or affected but a given organization can adopt and cope up with them. The authors conducted significant studies to identify the factors that affect the humanitarian logistics and developed a framework for understanding of the way local situational factors influence the performance of humanitarian logistics.

Kinyua (2013) conducted a study to identify the status of humanitarian response and factors (socio-economic situational, organizational internal, infrastructural situational and governmental situational factors) associated with its performance in humanitarian organizations in Kenya. The results of study revealed government bureaucracy and infrastructure emerged as the most important correlates of humanitarian supply chain performance. Whereas, cultural restrictions on supplies and procurement delays did not demonstrate any effects on supply chain performance. One of the study recommendation

is to undertake a comparative study on factors affecting humanitarian operations so as to draw similarities and parallels and build synergies so as to generate evidence for planning and decision making.

Wolde (2016) conducted a study to examine the antecedents of humanitarian logistics performance at IRC Ethiopia. The researcher found out of the eleven factors seven were found statistically significant. The significant factors are: donors' funds, environmental situational factors, professional staff, infrastructure situational factors, socioeconomic situational factors, and Institutional learning and government situational factors. In the same year, Shuria et. al (2016) determine the influence of organizational flexibility on humanitarian aid delivery effectiveness in humanitarian organizations in Somalia. The findings of this study concluded that financial flexibility, operational flexibility and resource allocation flexibility increases overall organizational flexibility within humanitarian aid organizations in Somalia. Table 1 shows summary of the factors that affect the performance of humanitarian logistics based on previous studies.

Table 1: Factors that affect the performance of humanitarian logistics	
Internal organizational factors	
Financial Resource	KINYUA (2013); Wolde (2016); Shuria et. al (2016)
Human Resource & Institutional learning	
Use of Information Technology	
Collaboration and Communication	
External situational factors	
Government situational factors	McLachlin and Larson (2011); Kunz and Reiner (2012); Kinyua (2013)
Adequate donors funding	
Socio-economic situational factors	Dowty and Wallace (2010); Kunz and Reiner (2012); KINYUA (2013) Kunz and Reiner (2012)
Environmental and Infrastructure situational factors	Chakravarty (2011); Nolz et al.(2011); Kunz and Reiner (2012); kinyua (2013); Majewski et al.(2010); Kunz and Reiner (2012)

## RESEARCH PROBLEM AND HYPOTHESES

Based on reviewing the literature, the research problem are summarized in the following research questions: What factors affect humanitarian logistics activities, in particular the response and recovery processes in Egypt? To what extent are each of the factors associated with humanitarian logistics activities?. Also, *the researcher designed the following hypotheses:*

*H1: There is a significant impact of internal factors on the performance of humanitarian logistics.*

H1a: There is a significant impact of Financial Resources on the performance of humanitarian logistics.

H1b: There is a significant impact of Professional Staff and Institutional Learning on the performance of humanitarian logistics.

H1c: There is a significant impact of Use of Information Technology on the performance of humanitarian logistics.

H1d: There is a significant impact of Collaboration and Communication on the performance of humanitarian logistics.

*H2: There is a significant impact of external factors on the performance of humanitarian logistics.*

H2a: There is a significant impact of government situational factors on the performance of humanitarian logistics.

H2b: There is a significant impact of donors funding on the performance of humanitarian logistics.

H2c: There is a significant impact of socio-economic situational factors on the performance of humanitarian logistics.

H2d: There is a significant impact of infrastructure and environmental situational factors on the performance of humanitarian logistics.

## RESEARCH METHODOLOGY

This research is mixed between descriptive and explanatory research. The research had applied the deductive approach (quantitative) using a questionnaire (Tashakkori et al, 2009). The questionnaire had been developed using the previous studies of (Kunz and Reiner, 2012; Kinyua, 2013; Wolde, 2016) where respondents were asked to rate their level of agreement regarding the statements on a scale from "1"(To no extent) to "5"(To a very great extent). The questionnaire had been adopted for several reasons; one of which is to investigate the influence of internal factors (Financial Resources, Professional staff and institutional learning, use of information technology and collaboration) and external factors (government situational factors, donors funding, infrastructure and environmental situational factors and socioeconomic situational factors) on the performance of humanitarian logistics (as shown in figure 1).

The population for this research is the Egyptian business experts engaged in humanitarian logistics in local and international humanitarian in Egypt. The research framework for the data collection was cross-sectional; as the data was gathered one time from Egyptian business the population under study. The researcher used a convenience sampling technique to select respondents from Egyptian experts of being engaged in human logistics activities in Alexandria, Egypt. Those respondents will be knowledgeable enough to notice and judge their organizations humanitarian logistics activities, ensuring that the research overcame the limitation of low level of awareness, which may distort the results and/or lead to small usable sample size (Nejati and Ghasemi 2013; Smirnova 2012). Sample size was determined as 10 observations per variable. Thus, sample size is 80 observations as the research includes 8 independent variables (Wolf et al., 2013).

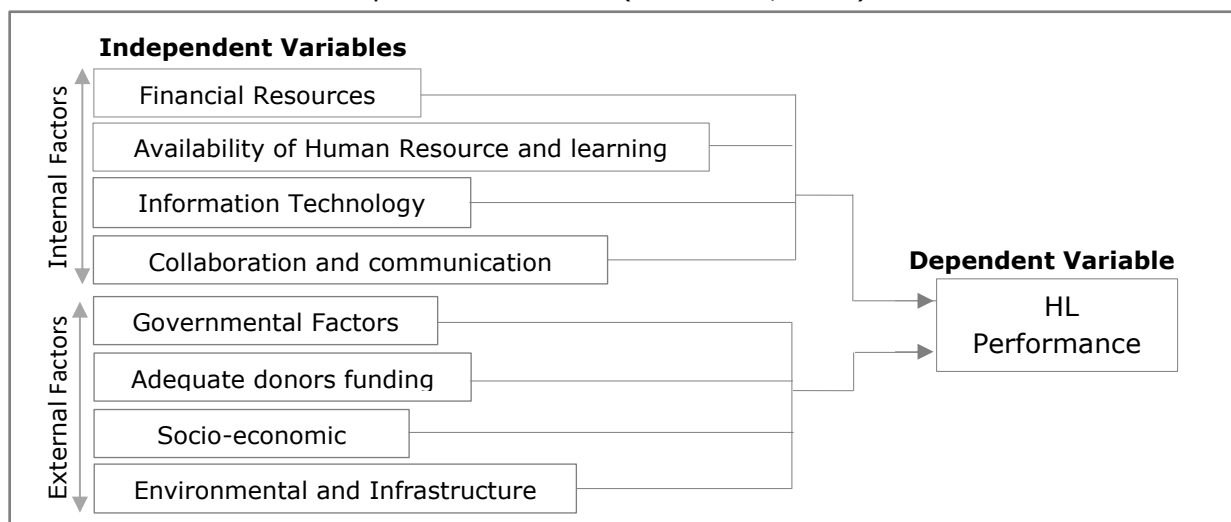


Figure 1: Research Framework

## RESULTS AND DISCUSSION

This section will present the empirical results and findings that the researcher obtained after applying the tools assigned above.

Data testing using Validity and Reliability

Validity is the degree of measuring the items of a certain construct in the right way (Sekaran & Bougie, 2010). The average variance extracted (AVE) and the factor loading (FL) are used to measure the validity of a certain construct, where AVE value should be at least 50% and FL should be 0.4 or more (Sekaran & Bougie, 2010). It was observed that the Kaiser–Meyer–Olkin (KMO) of sample adequacy and Bartlett's sphericity test. It was found that all KMO values are found to be between 0.500 and 0.766. Also, all P-values of Bartlett test were less than 0.05 (P-value = 0.000). In addition, all AVEs lie between 0.448

and 0.989. Such results imply adequate convergent validity. The result obtained after deleting some items from each construct.

Reliability is the degree of consistency between items of one construct. To test reliability of the research variables, Cronbach's Alpha, was applied. It was also noticed that the corresponding cronbach's alpha to research variables lie between 0.650 and 0.987, which is greater than the acceptable reliability coefficient level of 0.65. (Hair et al, 2003). Testing the discriminant validity of the research variables, it was found that all square root of AVE values are greater than the correlations between the corresponding construct and other constructs. This means that the research variables have adequate discriminant validity.

It was observed that the frequency table for each of the research variables, where it could be noticed that respondents were lying most in the third and fourth classes of moderate and great extents. This means that there is some shortage shown by respondents as they are not fully satisfied with the factors faced by their organizations.

### Testing the First Hypothesis

After testing the data, the researcher used regression analysis to respond to the research hypotheses. Regression analysis is a statistical procedure widely used to predict the value of one dependent variable based on the value of one or more independent variables. It is also used to understand which variable among the independent variables is related to the dependent one (Malhotra and Birks, 2007). Applying multiple regression analysis, where internal factors (Financial Resources, Professional staff and institutional learning, use of information technology and collaboration) are the independent variables and Performance of Humanitarian Logistics is the dependent variable, table 2 had been obtained. It could be observed that there is a significant impact of both; Professional staff and institutional learning as well as use of information technology on performance of humanitarian logistics ( $\beta=0.622$  and  $-0.302$ ; P-value = 0.000 and 0.000 respectively). On the other hand, there is an insignificant impact of both; Financial Resources and Collaboration on performance of humanitarian logistics (P-value = 0.503 and 0.056 respectively). Also, it could be observed that professional staff and institutional learning is the most important factor among the internal factors with respect to the performance of humanitarian logistics, as the standardized beta is the greatest (Standardized Beta = 0.653). Use of information technology comes in the second rank with standardized beta of  $-0.426$ . The least impact was found in Collaboration with standardized beta of 0.148 and Financial Resources with standardized beta of 0.050.

**Table 2: Multiple Regression Analysis of Internal Factors on Performance of HL**

Model		Unstandardized Coefficients		Standardized Coefficients	T	P-value
		B	Std. Error	Beta		
1	(Constant)	1.794	.582		3.082	.003
	Financial Resources	.064	.095	.050	.673	.503
	Professional staff and institutional learning	.622	.068	.653	9.189	.000
	Use of information technology	-.302	.052	-.426	-5.856	.000
	Collaboration	.167	.086	.148	1.944	.056

Thus, the first hypothesis could be partially accepted that internal factors have a significant effect on performance of humanitarian logistics.

### Testing the Second Hypothesis

Applying multiple regression analysis, where external factors (government situational factors, donors funding, infrastructure and environmental situational factors and socioeconomic situational factors) are the independent variables and Performance of Humanitarian Logistics is the dependent variable, table 3 had been obtained. It could be observed that there is a significant impact of all external factors; Government situational factors, Donors funding, Infrastructure and environmental situational factors and Socioeconomic Factors on performance of humanitarian logistics (P-value = 0.008, 0.000, 0.000 and 0.000 respectively). Also, it could be observed that infrastructure and

environmental situational factors is the most important factor among the external factors with respect to the performance of humanitarian logistics, as the standardized beta is the greatest (Standardized Beta = -0.615). Donors funding comes in the second rank with standardized beta of 0.515, then, Socio-economic situational factors with standardized beta of 0.327. The least important factor is Government Situational Factors, as corresponding standardized beta is -0.212.

**Table 3: Multiple Regression Analysis of Internal Factors on Performance of HL**

Model		Unstandardized Coefficients		Standardized Coefficients	T	P-value
		B	Std. Error	Beta		
1	(Constant)	1.984	.421		4.711	.000
	Government situational factors	-.124	.046	-.212	-2.716	.008
	Donors funding	.636	.128	.515	4.953	.000
	Infrastructure and environmental situational factors	-.382	.070	-.615	-5.493	.000
	Socioeconomic situational factors	.326	.076	.327	4.316	.000

Thus, the second hypothesis could be fully accepted that external factors have a significant effect on performance of humanitarian logistics.

Finally, a structural equation modelling will be fitted using AMOS to figure out the impact of internal and external factors on the performance of humanitarian logistics. It could be observed that there is a significant impact of External factors (P-value = 0.000), while there is insignificant impact of Internal factors (P-value = 0.061) on the performance of Humanitarian Logistics as shown in table 4.

**Table 4: SEM Results of the impact of Internal and External Factors on Performance of HL**

			Estimate	S.E.	C.R.	P
HL Performance	<---	Internal Factors	-2.202	1.178	-1.870	.061
HL Performance	<---	External Factors	-.912	.184	-4.966	***

The finding of the research contest with the previous studies for Maewski et.al (2010), Nolz et. al (2011) and Kinyua (2013) that stated that there are significant impact of shortage of well-trained logistics professionals and infrastructure and environmental situational factors.

## CONCLUSIONS

This study is a guide for humanitarian organization managers and all stakeholders to concern with Professional staff and institutional learning as well as use of information technology as internal factors and infrastructure and environmental situational as external factors to avoid any delays to transport and supply reliefs in response and recovery phases. The study opens new opportunities for researchers for further investigation for conducting comparative study targeting corporate sectors, development projects and specific emergencies in other geographical areas.

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# THE ROLE OF POWER ON PROCUREMENT AND SUPPLY CHAIN MANAGEMENT SYSTEMS IN A HUMANITARIAN ORGANISATION: A CONCEPTUAL FRAMEWORK

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## Abstract

This paper investigates the role of power on procurement and supply chain management systems and the decision-making process of the purchasing function in a humanitarian organisation. The paper provides a conceptual framework along with a set of research schemes that depict how the role of power leverages the working of systems. The concept of power is central to understanding the processes and structures of the purchasing functions in procurement and supply chain strategies. However, the value of exploring power is to understand how behaviour is influenced within the decision-making process and establish how the different bases of power affect the performance of an organisation. We argue that there is a need to explore the reasons for the success and failure of the humanitarian supply chain. This study challenges the current theories of supply chain management practices in humanitarian aid within developing-country contexts. In this way, this research provides new insights into procurement and supply chain management practices in a humanitarian aid, where disasters create demands that cannot be met by domestic resources. Subsequently, the search of understanding the role of power is significant in the development and successful procurement and supply chain management strategies.

**Keywords:** Power, Procurement, Supply Chain Management, Humanitarian Organisation, Socio-technical systems, Disaster.

**Category of paper:** Conceptual

## 1. Introduction

This research is a study of the role of power on procurement and supply chain management (P&SCM) systems. More specifically, the focus is on examining the decision-making process of the purchasing functions in the procurement process of a humanitarian organisation. Although, the nature and the work of a humanitarian organisation is to alleviate the negative impact of disaster situation, humans prepare counter measures by creating infrastructure and planning relief operations in advance (Farahani, Rezapour & Kardar 2011). Humanitarian organisations all over the world make extensive efforts to help nations and people to recover from disaster impact through quick responses and provision of aid supplies (Mwanjuma & Fridah 2015). Criticism has been levelled at the humanitarian system and performance for failing to meet the basic requirements of affected populations in a timely manner, with the quality of response varying greatly from crisis to crisis (Stumpenhorst, Stumpenhorst & Razum 2011).

Adequate responses are not an easy task for aid organisations, especially when confronting with complex impediments in providing necessary disaster responses (Akhtar, Marr & Garnevska 2012; Tomasini & Van Wassenhove 2009a; Van Wassenhove 2006b). Practitioners and academics have advocated that an efficient and flexible humanitarian relief operations is the key factor in disaster response perspective and saving lives (Kovács & Spens 2007; Whybark et al. 2010). Further, the associated level of uncertainty in demand, supplies and assessment (Van Wassenhove 2006b), lack of information and preparedness and recovery efforts (Charles 2010) with time pressure, considered as one of the biggest hurdles to overcome in humanitarian relief. Therefore, high degree of complexity is the determinate of humanitarian supply chain and logistics, which makes this area the most expensive part during humanitarian aid and relief operations of that being 80 per cent of total expenditures, that make the difference

between a successful and failed relief operation (Van Wassenhove 2006a). The reason for this high ratio is that humanitarian organisations in preparedness phase, pre-stock of critical relief items in strategic locations around the world as a strategy to improve the capabilities of humanitarian relief organisation in delivering sufficient relief supplies within a short timeframe (Balcik & Beamon 2008).

Although the role of procurement and supply chain management as a strategic support functions in the disaster response, the literature surrounding humanitarian relief operations mainly focused on technical challenges relating to coordination and collaboration, facility location, inventory management, logistics or transportations challenges (Balcik et al. 2010; Falasca & Zobel 2011; Tatham, P et al. 2010). The reliance on supply chains that span any operations is one of the key features of the humanitarian networks. However, such extensive supply chains are vulnerable to disruption and that that reliance can be influence by other areas of importance such as the social fabric within supply chains and networks. Organisation's competitive success factor becomes increasingly dependent upon the social and technological interrelatedness of an organisation (Emery, F & Trist 1960; Pettit & Beresford 2009), as such power interplay is crucial in this environment. Power as part of a control mechanism, social fabric and network has the potential to exert influence upon subordinates is implicit in all social relationships (Dahl 1957; Emerson 1962; Yukl 1989). To understand the concept of power, it is imperative to address various source and origin of power. This study, uses five sources of power (expert, referent, legitimate, coercive and reward) introduced by French and Raven (1959). Literature on organisations acknowledges the critical role of power, yet at its heart, there remains a lack of consensus about how the role of power influences the performance of systems in a humanitarian context which this research challenges to solve.

Nonetheless, despite extensive studies on P&SCM systems, and a growing body of literature reflecting the increasing importance of supply chain management in both normal business and humanitarian sectors, there is limited or no prior literature exploring the relationship between the role of power and P&SCM systems in a humanitarian context. Specifically, how power relation is different to another context. Researchers acknowledged the limited body of research in humanitarian logistics and supply chain (Glenn Richey Jr, Kovács & Spens 2009; Kovács & Spens 2007; Pettit & Beresford 2009). However, a number of important contributions have been made in this area, one of the earliest by (Long & Wood 1995). It is suggested that South East Asia tsunami of 2004 provided the catalyst for the current sustained level of interest (Christopher & Tatham 2014). Further, empirical studies that examine power, purchasing, decision-making process and supply chains process in a humanitarian context are scarce and limited in scope. But, there is emerging literature mainly focused on connection between the concept of power and the purchasing function in marketing channels (buyer-supplier perspective and pull and push strategies). These studies aimed to provide normative recommendations to buyers to achieve competitive advantage (Cox, A., Sanderson & Watson 2001; Gelderman, Semeijn & De Zoete 2008; Kraljic 1983). Nevertheless, these studies also lack an integrated and common operationalization of power between buyer and supplier. These studies are mostly conceptual with less empirical support explaining the relationship between purchasing strategies and buyer-supplier power structures. Another limitation in the literature is that the issue of power on humanitarian processes has rarely been connected and discussed in relation to each other in South Asian context. The above discussion highlights a problem in the research given the implication that the relationship between influence of power on business systems and the decision-making process is an unexplored area. To solve this problem the current research focuses on a strategic question: "How the role of power influences the decision-making process of purchasing function in a humanitarian aid procurement context".

## **2. Literature Review**



The challenge of securing the required resources, getting them to disaster spots, deploying resources and helping affected areas begin the process of recovery is undertaken by a sequential processes related to humanitarian relief supply chain (Day et al. 2012; Fritz Institute 2005). A supply chain is a network of organisations that are involved through upstream and downstream linkages in the different processes and activities that product value in the form of products or services in the hands of the ultimate consumer (Christopher 2005). Supply chain management is the management across a network of upstream and downstream organisations of material, information and resource flows that lead to the creation of value in the form of products and services (Mangan, Lalwani & Butcher 2008). There may be contextual differences in the business and humanitarian sectors, but supply chain management is the central to any given logistical operation (Van Wassenhove 2006b).

Humanitarian supply chain management comprises of all activities related to material, information and financial flows in disaster relief operations, it also includes coordination and collaboration with supply chain partners, third party service providers and other humanitarian organisations. It ensures the management and efficient flow of aid supplies, services and aims at alleviating human suffering (Jain et al. 2012). Performance of humanitarian supply chains are very instrumental in disaster relief operations and ensure preparedness, immediate response, reconstruction and recovery phase (Baumgarten, Kessler & Schwarz 2010). Each of these activities involve logistics support, even though every phase has its requirements in terms of duration, volume, the needed in addition to the variety of supplies, urgently and procurement support (Abidi, de Leeuw & Klumpp 2013) so that a sustainable supply chains can be achieved.

In seeking for sustainable supply chains, procurement plays a proactive role and contribute to the bottom line of any organisation (Rudzki et al. 2005). In the first instance, it plays a vanguard role in acquiring humanitarian supplies for non-governmental organisations and other aid agencies. Those organisations spend a rough estimate of USD20 billion annually worth of goods and services during initial time of disaster, either from local or international sources and vendors (Tatham, P. & Pettit 2010). Procurement is defined as "all the activities required to get the product from the supplier to its customers" (Van Weele 2010, p. 407), who suggested that procurement encompasses all purchasing functions and to be used when "relating to buying based on total cost of ownership" and not price matter. It includes processes responsible of all actions required in order to get the goods and services from the supplier to its final destination at the best possible cost to meet the requirements of the purchaser in terms of quality, quantity and time (Mangan, Lalwani & Butcher 2008). Humanitarian focused-procurement activities play a pivotal role in the supply chain process of humanitarian relief operations. Disaster-driven supply chains are typically formed as 'incident-responsive ones' with short-term formations of different resources (Smith & Dowell 2000). Within this unprepared structure that attempts to save lives and provide rescue and relief, "the need for successful supply chain management is unparalleled" (Day, Junglas & Silva 2009, p. 638).

A profound investigation into humanitarian aid operations, Tomasini and Van Wassenhove (2009b) have given priority to only individual facets such as logistics or human resource management as parts of supply chain. However, professionals refer to involvement of a wider aspects (Vega & Fabee-Costes 2011). Finding from other research referred to the level of uncertainty that supply chain operates during humanitarian relief operations in terms of disaster timing and location, demand, donor's suppliers, nature and intensity of disaster (Balcik et al. 2010). Jahre, Hensen and Listou (2009) investigated the challenges in humanitarian supply chain and how the balance between the ability to respond to a crisis and necessity of being cost effective are important when reacting to a crisis. Hence, the concept of "Agility" and "lean" were studied and proposed to the humanitarian supply chains (Oloruntoba & Gray 2006) and integration of both (L'Hermitte et al. 2015; Mason-Jones, Naylor & Towill 2000). Similarly, scholars found that the effectiveness of the disaster relief operation depends

on the agility principles within a supply chain (Charles et al. 2010; Christopher & Tatham 2014; Christopher & Towill 2001; Cozzolino 2012; Glenn Richey Jr, Kovács & Spens 2009; Oloruntoba & Gray 2006; Pettit & Beresford 2009; Scholten, Scott & Fynes 2010; Taylor & Pettit 2009). Agility is "the ability to successfully effect, cope with, and/or exploit changes in circumstances" (Alberts 2011, p. 190). Thus, agility focuses on that non-adverse change can be exploited to improve performance. With continuously working in environments with high degrees of uncertainty, aid organisations end up becoming specialists in the implementation of agile systems (Charles et al. 2010).

However, the agility does not ignore the lean principles 'the major generic strategies in supply chain' (Christopher 2005); rather, both principles can work within a supply chain at different time and place (Childerhouse & Towill 2003; Christopher 2005; Mason-Jones, Naylor & Towill 2000; Scholten, Scott & Fynes 2010), and may also work within the emergency supply chain (Scholten, Scott & Fynes 2010). Scholten, Scott and Fynes (2010) and Cozzolino (2012) posited that the principles of agile and lean have advantages in humanitarian context which ensure the performance of the entire emergency and supply chain operations and managing the resources. Mason-Jones and Towill (1999) emphasised that, the Lean and agile are distinctly different paradigms, but when combined in a single model, contribute to the success of a supply chain. Both paradigms are depend on the strategy, market knowledge, enrichment of information and the positioning of the decoupling point between the tow. In reality the tow paradigms can complement each other, as there is requirement for a "Hybrid" model of lean/agile strategy to be adopted (Christopher & Towill 2000) in some cases as 'leagile' solution (Naylor, Naim & Berry 1999).

Although the lean and agile principles have been practiced in the field of supply chains, practically lean principle does not entail agility. Agility is more significant, due to the life-saving objective guiding the work of relief agencies. Hence a strategic use of the resources within humanitarian operations can assist the large number of people in their survival and raise donor trust and long term commitment (Scholten, Scott & Fynes 2010). This can be noticed in recent earthquake disaster situation in Himalayan nation of Nepal in April-May 2015 where the scale of the disaster, the capacity limit of the Kathmandu airport and its resultant incapability to cope with the flow of humanitarian supplies, and the topographic characteristic of some of the areas struck, have directed humanitarian organisation to look for agile solutions to overcome these challenges and get the urgently needed life-saving supplies on the ground (L'Hermitte et al. 2015). To realise agility in complete capacity, an organisation or system must have resilience in addition to responsiveness, versatility, flexibility, innovativeness and adaptability (Collier & Linkov 2014).

In contrast to vulnerability of disasters, researchers explored the usefulness of the resilience concept to humanitarian area (Holling 1973) who described two different aspects of change in an ecosystem over time, (Comfort, Boin & Demchak 2010; Mayunga 2007; Paton & Johnston 2006). In the business environment, the resilience concept was a result to find ways to develop strategies for preventing and coping with different types of disruptions (Roberta Pereira, Christopher & Lago Da Silva 2014). Also, because it's broad application to different topics for example, ecology, psychology, economy, social and organisational perspective, the resilience concept has become a 'multidimensional and multidisciplinary phenomenon' (Roberta Pereira, Christopher & Lago Da Silva 2014) in the last decades (Ponomarev & Holcomb 2009), coping with disaster (Miao & Banister 2012; Miao, Banister & Tang 2013). Supply chain resilience is defined as "the ability of a system to return to its original state or move to a new, more desirable state after being disturbed" (Christopher & Peck 2004, p. 5333). The resilience concept is also relevant to coping capacity of human systems during crisis.

In the disaster literature, researches showed that humans behave in a compassionate manner during and immediately after a disaster situation without much panic or anti-social behaviour immediately after a crisis (Fischer 2002). However, findings from other studies have reinforced the significance of investigating human behaviour in the

aftermath of disasters and the need to conduct more social research in this area because human behaviours and social factor are critical to any successful response to disasters (Drabek & McEntire 2003). In already chaotic situations, not surprisingly, the involvement of human actors in the performance of organisational tasks, involved in a humanitarian aid system is managed and characterised by multiple actors and decision making structures and return to original state or move to a new state (Christopher & Peck 2004; Holling 1973). Without disputing the importance of supply chain concepts is centre to success of operation in business environment. However, neither of these concepts attempts to work in separation of the information technology in an organisational setting. Information technology (IT) is referred to the systems within an organisation that "collect, process, store, analyse, and disseminate information" (Turban, Rainer & Potter 2007, p. 2). These systems include not only hardware and software but also people and processes. Jasperson et al. (2002, p. 427) asserted that "the creation and introduction of IT can be seen as a process that involves interested parties intentionally using their power to affect the nature of the systems that are put in place". As such, IT may impact not only on reinforcement but strengthening power differentials (Melville, Kraemer & Gurbaxani 2004).

The multifaceted conceptualisations of power and its relevance to the IT can be analysed from different perspectives. From one perspective, IT might be understood as a change factor within power structures and processes (Hensel & Schkade 1995). Alternatively, the introduction of IT could be understood as a process that involves interested parties to intentionally use their power to affect the nature of the systems that are operated (Jasperson et al. 2002). At complex level, expectations regarding changes to power structures and power assist as an important factor in decisions to embrace, promote, or advance IT, even if the actions that result are not themselves particularly power-laden or political (Jasperson et al. 2002). IT is used to create 'symbols and meaning' in organisations that strengthens existing power structures or to 'meld altered structures' (Jasperson et al. 2002). Organisational power is derived from many sources mentioned earlier and can also stem from ownership, providing resources, capitalising upon opportunity, and being close to source of power (Patrick 2012). The above discussion indicates that the focus is on the bigger picture rather than the detailed challenges in the disaster processes. The study therefore proposes a conceptual framework, which explores the relationships between power and supply chain process based on the identification of key factors within an organisation (Appendix II-Figure 1). Human factors such as the impact of power leverage on supply chain performance will be envisaged by using the extracts of inter-firm power found in supply chains, the one established by (Maloni & Benton 2000). Appendix-I (Figure 1) depicts this model.

The discussion above provides a unique research area, hence this paper has two specific objectives; first, develops an analysis of social issues associated with the power in the existing theory to arrive at assumptions of how it will influence the performance in a humanitarian organisational setting and how it is difference to other settings; this can provide direction for further research in this area. Second, explores the social aspect of power and uncovering its influence makes it possible to contribute to socio-technical system theory from this particular context. This is a salient point of reference because the setting is characterised by challenging the social fabric, complexity and high level of uncertainty. Moreover, a particular focus to scrutinise the decision-making process of the purchasing function in a humanitarian organisation context is delineated. The next section discusses the power concept.

## **2.1 Origin and Breadth of the Power Concept – An Overview**

There is no doubt that power is a highly contested concept (Giddens, A. 1982; Huagaard 1997; Knights & Morgan 1991). The reason why is contested, because there are different definitions, perspective and conceptualisations (Dahl 1957) and understood by authors in variety of ways (Eyben 2006). The literature on power delineated this problem, the absence of clarity over power phenomenon; with agreement that, power is an extremely troublesome, elusive, notoriously evanescent and subjective concept (Bachrach & Baratz

1962; Ramsay 1996); a term that vague, poorly defined 'primitive' (Hage 1972); and difficult to pinning down exactly what it is (Clegg, S., Courpasson & Phillips 2006). Finally, Cartwright (1959) found that, many authors 'invent' their own definitions in order to suit their needs.

The definitions of power known today have a root from different school of thoughts; power is generally conceived of as the ability of one social actor to prevail over another's resistance in attaining a desired result (Pfeffer 1981; Russell, B 1938). In tendency to view power in zero-sum terms, researcher viewed it as a property of agents: individual or collective entities such as firm, governments or political parties (Dahl 1957; Dowding 1991; Morriss 2002; Simon 1953; Weber 1978). Others, argued that power is a property of systems or structures (Clegg, S 1989; Foucault 1980). Some contend that power is ubiquitous and obscure and hence cannot be measured (Lukes 2005); others viewed power as necessarily conflict; involves the clash of interests or plans and what one gains another loses (Dahl 1957; Lukes 2005; Weber 1978). Whereas, others viewed power in positive sum terms; presented power as consensual; that is, social power is about people working together to accomplish goals that could not be accomplished alone hence increasing their collective power (Arendt 1972; Barnes 1988; Parsons, T. 1963). Others used power definitions that include conflict and consensual elements such as (Clegg, S 1989; Dowding 1991; Foucault 1980; Giddens, A 1984; Haugaard 1997; Morriss 2002).

Dahl (1957, p. 202) definition of power is universally accepted and significant in this study, Dahl stated that "A has power over B to the extent that he can get B to do something that B would not otherwise do". Dahl (1957) referred to power as the capacity to controlling of someone else's behaviour and or action despite resistance. This relational definition is accepted, nonetheless, it is also contested by many others. Given that power tends to be a complex phenomenon influencing the social fabric, it is critically important to give power due considerations in supply chain and network since it can seriously impede cooperation through power interrelatedness with other factors (Cox, A 2001).

## **2.2 Power in Supply Chain**

Bacharach and Lawler (1980, p. 14) stated that "when doing research in order to capture the term of power we must identify a more concrete phenomenon or idea to which the primitive term points". A study of power within the supply chain is complicated, because there are many conceptualisation. For example, in marketing channels, majority studies on power are based on work of El-Ansary and Stern (1972, p. 47), who's defined power as "the ability of a channel member to control the decision variables in the marketing strategy of another member in a given channel at a different level of distribution". Other studies focused on the behaviour of marketing channels and supply chain relationships (Cox, A., Sanderson & Watson 2001; Maloni & Benton 2000; Ramsay 1996).

Cox, A. et al. (2002) presented the concept of control over critical assets, defined power as "the ability of a firm to own and control critical assets in markets and supply chains that allow it to sustain its ability to appropriate and accumulate value for itself by constantly leveraging its customers, competitors and suppliers". The concept of critical assets and or resources in supply chain is based on the idea that "some resources are considered scarce or unique and that with the combination of high value, uniqueness and scarcity, particular supply chain resources become critical assets" (Hanf, Belaya & Schweickert 2012, p. 229). Resources are highly valued by the organisation and considered as one of the major structural sources of power (Salancik & Pfeffer 1977). Hu and Sheu (2005, p. 448) described power as "a strategy-influencing source that is oriented from one channel member to another". The result is that power is labeled as 'effectively applied means to gain certain objectives' by using influence strategies, once the power over another firm was achieved (Hu & Sheu 2005; Payan & McFarland 2005).

Much of the existing research has attempted to recognise a range of sources that affect internal power of an organisational member (Chung & Kang 2013). This research

observe French and Raven (1959) power bases as the conceptualisation of the elites power construct, they stated that "process of power is pervasive, complex, and often disguised in our society" (French & Raven 1959, p. 150). French and Raven (1959) has offered one of the most comprehensive frameworks to understand the source of power (Fiske 2011). This is because, it has a wider scope and dimension of power which organisation elites achieve desired outcomes. These differences in the dimensions suit the type of problem the current research investigate. Appendix-I (Table 1) provides a list of differences in the sources of power. The next section describes the theoretical underpinning.

### **2.3 Theoretical Background - Socio-technical Systems Theory (STS)**

The role of people and social fabric has been reported to be of great importance in organisational operations. The need for a flexible system structure allows the integration of different variables such as social and technological systems when aiming for optimisation (Trist et al. 1963). Socio-technical systems (STS) thinking assists in identifying those areas that are concerned with the operational and organisational aspects of organisational system (Trist & Bamforth 1951). Bruijn and Herder (2009, p. 981) described STS as "systems that involve both complex physical-technical systems and networks of interdependent actors". The important contribution of this framework is that the system behaviour can be analysed and improved only by considering both social and technical systems and their interdependencies (Ottens et al. 2006). STS is more significance in this analysis among other theories. The theories investigated in this work were Network theory, Actor Network theory, Agency theory, General System's theory, Organisational theory and Institutional theory, as those theories may have drawbacks.

The socio-technical systems term was coined by Trist and Bamforth (1951) to describe a method of understanding organisations which focuses on the "interrelatedness of the functioning of the social and technological subsystems of the organisation and the relation of the organisation as a whole to the environment in which it operates" (Pasmore et al. 1982, p. 1181). In other word, the STS theory posited that an organisation are composed of people the make goods or services using tools and technology, and that each affects the operation and appropriateness of these tools and technology and actions of the people who using these tools and technology (Butera 1975; Emery, F & Trist 1965; Emery, T. 1959; Trist 1978; Trist et al. 1963). One of the key benefits of the STS approach is its ability to effectively analyse complex problems in a holistic view (people, tasks, structure and technology) because it addresses organisational settings in which people are required to perform tasks and to produce desired outputs (Bostrom & Heinen 1977; Griffith & Dougherty 2001; Passmore & Sherwood 1978). In order to accomplish organisational goals, the interrelatedness of social and technical subsystems should be optimised jointly, as early studies proposed (Cherns 1976; Passmore & Sherwood 1978). The socio-technical system approach argues that organisations are made up of people that produce goods and services using some technology in which affects the operation and appropriateness of the technology as well as the actions of the people who operate it (Pasmore et al. 1982). STS provided us with a good starting point in the current investigation.

The STS concepts best fits with the research purpose, because first STS fit with complexity and the aspect of power on P&SCM systems in a humanitarian setting. Second, and most important, central to this complexity is the notion of social and technical nature of P&SCM systems. Hence, supply chains can be typically seen as social-technical systems. From one perspective, the supply chain is a network of technical factors, for example production, procurement, logistics, warehouse etc. which are physically interrelated: the flows of inputs from suppliers through a process and finally to retailers and final consumers if different location. Each of the physical nodes and links in this extended network may contain several other physical subsystems. On the other perspective, in any supply chain, suppliers, manufacturers, retailers and customers produce a social network with various interactions. More significant, the decision in the social network also, is leveraged by characteristics of physical components in the supply

chain. As a result, a successful supply chain is the output of behaviour of both social and physical networks and the interactions and interrelatedness between these networks (Behdani 2012; Ghiani, Laporte & Musmanno 2004).

#### **2.4 Links between Organisational Components – Leavitt Diamond**

Leavitt (1965a) offered a scheme about the nature of organisations that demonstrates the links between organisational components. Leavitt recommended that an organisation should not be thought of as "static charts or as milling collections of people or as smoothly oiled man-machine systems, but as rich, volatile, complicated but understandable systems of tasks, structures, tools (technology), and people in states of continuous change" (Leavitt 1965b, p. 317). All these components are interrelated and mutually adjusting, recognises the complex nature of social systems (Leavitt 1965b). Most importantly, observing changes, for example, when technology is changed, the other components often adjust to damp out the impact of innovation (Keen 1981). However, Leavitt warned "we must never for a moment forget that when we tamper with any one of these variables, structure, or technology or people, we are likely to cause significant effects on the others, as well as on the task" (Leavitt 1965b, p. 325). Often, multifaceted relationships need a simple method to their understanding. Humanitarian organisations are one example; by its nature that exposes the details of the socio-technical nature of systems and changes as seen in (Cassill 1977). Leavitt suggested that an organisation can be changed by manipulating any of these organisational variables. This illustrates a resilience model in which a system has the ability to survive changes despite severe impacts such as changes in organisations. In other words, the ability of a system to return to its original state or move to a new desirable state after being disrupted, as they observed implicit in this definition is the notion of flexibility (Christopher & Peck 2004). These changes illustrated in Table 2.

We set out to identify the organisational changes using Leavitt's diamond (organisation alignment model) this model provides simple and convenient key units for classifying our concept and notion of a humanitarian organisation. In this context; we adopted the definition of Leavitt of an organisation. Leavitt's structure of an organisation reflects the classical socio-technical systems design that discussed by (Trist 1981, p. 24) "relationship represents a coupling of dissimilar which can only be jointly optimized". In order to define systems, we build on the sociology of technological perspectives (Hughes 1987; Pinch & Bijker 1987). technology has no power by them; they do nothing, only in association with human agency and social structures and organisations, technology completes functions Fleck (1993). For example, in reality, organisations, houses and cities, never encounter technology 'per se', rather, technology-in-context (Geels 2005). For the analysis of functioning technology, it is the organised combination of the 'social' and 'technical' that is the appropriate unit of analysis (Fleck 1993). Appendix II (Figure 2) depicts Leavitt Model (Leavitt Diamond).

### **3. Research Conceptual Framework**

The study explores a humanitarian relief organisation by identifying the four components of Leavitt's model in conjunction with French and Raven framework of power bases to identify the power aspect of each of these components as part of large system. The power issue that emerges here presents the interrelationship of system and actors in the large system. The outcome of the systems reveals how successful the role of power is perceived on workings of these systems (see Figure 3). From extant literature, we have seen the potential complexity of an organisation as a technological system. Technological systems consist of messy, complex, problem-solving components. They are both socially constructed and society shaping (Bertalanffy 1968; Parsons, T 1964). We therefore, considered the applicability and draw from and operationalize the STS to analysing the dynamics systems such as P&SCM systems can demonstrate. Social shaping of technology investigates how a range of social and economic factors, as well as technical factors, patterns the design and implementation of technology (Mackenzie & Wajcman 1999).

The locus of this research is that P&SCM systems are one use of organisational processes that truly link technology and people into a social and technological system sphere, where technology and people interact in a complex set of actions and reactions within the flow of information and the influence of power (Fuller & Trower 1994). That is, an organisation comprises of people (actors = managers, operators and users) interact through, and with, computerised information and communication systems to perform and achieve collaborative work. Hence, collaborative work can be completed by groups and teams that emerge as an important means for managing an organisation (Goodman 1986) as emphasized in STS constitution. Bolton and Foxon (2015) highlighted that the STS approach is situated within the wider field of 'social shaping of technology', because a basic premise of STS is that the transformation of technologies and technical systems is not determined by any scientific, technological or economic rationality, rather there are a wide range of social, political and institutional factors that interact in a systemic fashion to influence their development (Bijker et al. 1987; Hughes 1983, 1987; Pinch & Bijker 1987; Russell, S & Williams 2002). An example of a social factor is the role power plays to influence interactions in a systemic fashion of technology and people. The STS approach reduces complexity, and tries to create efficient product flows (De Sitter, Den Hertog & Dankbaar 1997). Moreover, the STS approach examines the relationship of social and technical subsystems and its implications on organisational performance as this assists in exploring the role power plays in within STS components including people, tasks, technology and structure.

Based on the above discussion, this research uses STS theory as a theoretical underpinning to investigate factors that can influence procurement in the supply chain process of humanitarian aid operations. A humanitarian relief organisation's system is one example of an automated organisational communication and technological facets, which links technology and organisational participants under a socio-technical system thinking (Trist & Bamforth 1951). A socio-technical approach to humanitarian organisations acknowledges that organisational and human outcomes can be improved by striving for fit between the social and technical elements of the organisation (Katz & Kahn 1978, p. 701). Humanitarian organisation systems (HOs) can be seen as an example of a complex organisational arrangement, which links technology and organisational participants in a social technological system as they function together (Trist & Bamforth 1951). In HOs, the social components of an organisation are combined with the technical components in an effort to create a balance and synergistic relationship utilising the resources and technological innovations available. Thus, in HOs, people interact with and through uses of technology that includes a mediated communication system to accomplish collaborative work. This reflection could be applied to current humanitarian relief organisations working in disaster situations. Nepal is a real-life case-research where humanitarian organisations are entirely involved in relief operations, with the primary objective of conducting relief and rescue operations of survivals. However, understanding a humanitarian organisation's system by a socio-technical perspective suggests that organisational design efforts should not be entirely separate from technical considerations (Emery, F & Trist 1960; Emery, T. 1959; Emery, T & Thorsrud 1969).

#### **4. Conclusions**

This paper has made an important contribution to the literature related to power, procurement, supply chain management and decision-making process in a humanitarian context. This aim of this paper was to explore and understand the relationship between the role of power and performance of business systems in a humanitarian field during disaster. Initially, the emphasis is not on how systems perform in a disaster situation. However, the focus was on the role that power plays in the decision-making process of the purchasing function as part of the procurement activity in a humanitarian organisation. The complexity of this relationship is illustrated through a variety of supply chain disruptions; this, in turn, indicates the role of social fabric and technical system causes a ripple effect on the supply chains. In this paper, we explored the role of power on procurement and supply chain management systems by using a conceptual

framework. The investigation sought to outline that social fabric of procurement and supply chain management systems can leverage organisation's operational performance. To that end, STS system theory was used to support our argument and define the scope of the current research. STS viewed then discussed as a foundation for defining a humanitarian organisation practices. The framework suggested provides many advantages: it integrates three approaches; STS, Leavitt diamond model and French and Raven framework to provide comprehensive data capture and analysis. To sum, given the complexity of disaster and humanitarian organisation as a socio-technical systems, designing agile and therefore resilient systems is a difficult task.

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# **RISK ASSESSMENT FOR DISTRIBUTION OF PHARMACEUTICAL PRODUCTS ACROSS SUPPLY CHAINS**

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## **ABSTRACT**

### **Purpose**

The health and safety of patients depends on the pharmaceutical product quality and integrity, and weak links in the supply chain can cost lives. The aim of this paper is to identify and assess the risks during transportation of pharmaceutical products from the manufacturing site to the final customer. A supply chain risk assessment was carried for company X based in Mauritius, in relation to shipments for the Australia Asia (AusAsia) region since monthly quality management reports show increasing number of distribution complaints.

### **Design**

A failure mode and effect analysis (FMEA) was executed to propose actions in order to proactively mitigate all possible failures during the supply chain process to preserve the quality, safety and efficacy of the products. This process was performed in compliance with ICH Q9 (2006) guideline on quality risk management of pharmaceutical products.

### **Findings**

The FMEA revealed a number of risks items related to temperature excursion, delayed order and potential contamination. Corrective actions and preventative actions were put in place to reduce these risks to an acceptable level.

### **Originality/value**

The paper provides a comprehensive risk assessment methodology that promotes a thorough understanding of the risks across supply chains, on each distribution stage and mitigates risks which can costs patients' lives. A mixture of qualitative and quantitative approach was applied, with the main focus on the quantitative part.

**Keywords:** Supply chain, risk assessment, failure mode and effect analysis, good distribution practices

**Paper type:** Research paper

## **INTRODUCTION**

Distribution forms an important activity of the integrated supply chain management of pharmaceutical products (WHO, 2005). Marc *et al.* (2010) define a pharmaceutical product as a substance or combination of active pharmaceutical ingredients (APIs) and excipients, or preservatives which has a therapeutic, prophylactic, or diagnostic purpose, or is

intended to modify physiological functions, and is presented in a dosage form suitable for administration to the patient.

Inadequate control of distribution routes from the manufacturing to the final customer is a problem in any industry (Barton, 2014). However in the pharmaceutical industry weak links in the supply chain can cost patients' lives since the health and safety of patients depends on the product quality and integrity. In order to maintain the original quality of the pharmaceutical product, every activity during the distribution process should be carried out according to the principles of good manufacturing practices (GMP) and good distribution practices (GDP).

Company X, based in Mauritius, is a global supplier of branded and generic pharmaceutical products as well as infant nutritional and consumer healthcare products in selected territories. The company manages and maintains the intellectual property rights, regulatory and commercialisation strategy of its products as well as performing all of the procurement and supply related operations. The company was established for the purpose of buying and selling of pharmaceutical products in international markets. It does not perform any manufacturing activities itself but outsources the manufacture of a range of pharmaceutical products to both, its subsidiaries and other external manufacturing companies. When deals are acquired, technical information and knowledge acquired from previous product owners are inherited (e.g. manufacturing, regulatory, quality, use of existing service providers etc.).

All the manufacturing, packing, release, distribution and quality control of the products are carried out overseas. The technical agreement between the company and the manufacturing site defines the responsibility of GMP aspects of the various activities. It also specifies the way in which the responsible person releasing product batches for sale ensures that they comply with the marketing authorization. The qualified person at each specific contracted site is delegated with the authority and responsibility to generate, verify and implement all quality control and quality assurance procedures and ensure compliance of all products to quality control specifications.

Company X provides support to its affiliates and distributors by ensuring physical movement of goods is carried out once the approval is given to the Logistics Team. The company has contracted out the worldwide logistic services to DHL for the distribution of products from sites of origin to the destination sites. DHL must ensure that the products are shipped within specified conditions and in accordance with manufacturing and marketing authorizations.

Harold and Michael (2013) stressed that government regulatory agencies require pharmaceutical companies to provide an assurance that the products are safe and effective. The US FDA (2015) states that companies must have the process controls designed to assure the products possess the defined critical attributes of strength, quality, identity and purity. Therefore companies that manufacture and distribute regulated healthcare products have an obligation to meet these requirements and to provide safe products that meet the claims of effectiveness.

Temperature exposure outside acceptable limits increases the risk of product quality being compromised by temperature excursions beyond acceptable ranges. WHO (2011) defines temperature excursion as an event in which the time-temperature sensitive pharmaceutical product (TTSP) is exposed to temperatures outside the range prescribed for storage and/or transport.

Stability studies are needed to define the handling and transport conditions of TTSPs (Ammann, 2013). Kinjal and Rina (2012) define stability as the capacity of a drug substance or drug product to remain within established specifications to maintain its identity, strength, quality, and purity throughout the retest or expiration dating periods.



Temperature is the main focus for testing because almost all pharmaceutical products are sensitive to temperature and transport in controlled conditions is not always reliable.

Mathews and Kumar (2015) observe that products sensitive to high temperatures can deteriorate by receiving thermal energy that will decrease the active ingredient content through transformation of degraded components (oxidative, hydrolyzed), some of them with possible toxic properties. Temperature excursion can have a significant impact on quality, efficacy and safety of products. If the temperature excursion happens during the shipment, it needs to be properly assessed prior to releasing the batch to the market. If the impact of temperature excursion is not detected and communicated effectively on time, there can be potential delays in dosing patients.

This paper highlights (i) the appropriate risk assessment tool for shipment of sensitive products across a supply chain, (ii) the basic differences between a qualitative and quantitative risk assessment that helps to decide which method best suits the needs of service organizations dealing with distribution of pharmaceutical products, (iii) the shipment process from the manufacturing site to the customer with third party involvement, (iv) a high-level process map for each mode of transport (air, sea and road) to identify clear responsibilities for each relevant stakeholder, (v) all potential failures that can happen within the supply chain, (vi) the risk for each potential failure, and (vii) provide recommendations based on the findings to reduce the probability of occurrence of harm and the severity of that harm. Company X has been used as a case study for the purpose.

## **METHODOLOGY**

The first objective of the study was to identify the appropriate risk assessment tool for the case study. Review of the literature reveals different risk assessment tools as recommended by ICH Q9 (2006) guideline on quality risk management such as Hazard Operability Analysis (HAZOP), Preliminary Hazard Analysis (PHA), Fault Tree Analysis (FTA), Hazard Analysis and Critical Control Points (HACCP), and Failure Mode Effect Analysis (FMEA).

FMEA was the chosen for this research based on the requirements of this research where the aim was to proactively analyze and mitigate root causes of process quality risks within the global supply chain context. FMEA was carried out in line with ICH Q9 (2006) guideline to identify how the supply chain may fail, the potential failure effects, possible causes of failures and the likelihood to detect the failures before they occur. The final step was to prioritize actions to eliminate or reduce their chance of occurrence.

The FMEA team representatives were made up of individuals from various departments including quality associates, supply chain and logistics associates, regulatory affairs associates, packaging associate, quality team leader, and supply chain and logistics team leader. The aim of the team was to reveal any kind of uncertainty that could affect the FMEA output such as gaps in understanding the supply chain process, sources of harm (e.g., failure modes of a process, sources of variability), and probability of detection of problems (ICH Q9, 2006). Hence to avoid any subjectivity, careful consideration was taken to include people in the team who have extensive experience with the process and who can share historical data which is vital while assigning severity, occurrence, and detection scores. The FMEA ratings were defined for both the quantitative and qualitative risk assessment using the guidance from ICH Q9 which define the following parameters for risk assessment: Probability of occurrence, Severity and Detectability.

### ***Quantitative Risk Assessment***

The use of a 5 point Likert scale for each of probability, severity and detectability led to the development of the Risk Priority Number (RPN) score for each risk. The RPN value is an index used to evaluate current controls and make a call whether to prioritize failure

modes for action (David, 2007). Table 1 shows the relationship between the RPN scores and the actions to be taken.

Table 1 Relationship between the RPN scores and the actions to be taken based on quantitative assessment

RPN Score	Actions to be taken
Less than 10	Risk is <a href="#">acceptable</a> provided cost or effort to control the risk further is very low
11-20	Risk is <a href="#">low</a> . Action is required to reduce the risk, although low priority. Time, effort and cost should be proportional to the risk.
21-50	Risk is <a href="#">medium</a> . Action required urgently to control. Interim measures may be necessary in the short term.
51-100	Risk is <a href="#">high</a> . Action required urgently to control risks. Interim measures required in the short terms. Significant effort and time may be used to control the risk.
Above 100	Risk is totally <a href="#">unacceptable</a> , immediate action is required before the work activity can continue.

[Source: Adapted from [Baig \(2010\)](#)]

### Qualitative Risk Assessment

The qualitative risk assessment does not use numeric values to evaluate the risk in an organization. The risk was expressed using qualitative descriptors, such as low, medium and high. The risk level was then combined with the level of detection in order to assess the acceptability of the risk classified as acceptable, unacceptable and intolerable risks. Table 2 shows the matrix that was developed and used for initiating actions in the light of results obtained when probabilities and severities generated high risks.

Table 2: Matrix for assessing the acceptability of risk based on qualitative assessment of probability, severity and detectability.

MATRIX 2				
Risk Class = Detectability x Risk		RISK		
		Low	Medium	High
DETECTABILITY	Low	Unacceptable risk	Intolerable Risk	Intolerable Risk
	Medium	Acceptable Risk	Unacceptable risk	Intolerable Risk
	High	Acceptable Risk	Acceptable Risk	Unacceptable risk

## RESULTS AND DISCUSSION

### FMEA by air freight

For shipments by air, data loggers are required for all product types and the requirements are captured in the technical agreements with manufacturing sites. LSPs are responsible to ensure temperature-controlled service (2-8°C for cold chain, 15-25°C for ambient) is provided, wherever possible. Active or passive packaging is also used to further mitigate

the risk of exposure to variable environmental conditions. The use of such packaging system is used on a risk-based approach, that is the rationale is based on a combination of the following factors - nature of the product being shipped, intensity of past excursions, and recurrence of complaints, value of product and its cost of replacement (e.g. cost of manufacture or cost to patient supply) etc.

Thermal covers and pallet shippers are the most common type of passive packaging used. Thermal covers are included at the LSP hub for ambient products prior to being shipped out via instructions stipulated in the shipping documents. For example cold chain orders are currently packed into pallet shippers. Other manufacturing sites protect their orders with insulating foil wrap. Active temperature controlled service, which is a premium service, is used for critical products so that temperature control is guaranteed.

The FMEA by air freight reviews the potential failure modes when transport of pharmaceutical products loads by air. Four functions were identified for the process flow including the customer, company X, the manufacturer and the LSP. A process map was produced to highlight the activities having a potential to impact the quality of the products or influence the variable conditions which are expected during transportation. Following completion of the process map, each of the steps in the process map was reviewed and potential risks for each step were identified and ranked. These outcomes were added into the FMEA results table and ranked by RPN.

### ***FMEA by sea freight***

Shipments by sea are for high volume orders and use reefer containers, which use active temperature control system. The orders are loaded into the container at manufacturing sites or loaded at the LSP hub depending on the agreed incoterms. Reefer containers are used and the temperature settings can be customised. For non-cold chain shipments, reefer containers are set at 20°C but if consolidated shipments contain a mix of cold chain and non-cold chain shipments, reefer containers are set at 5°C. The risk of shipping non-cold chain orders at 5°C is minimal and supported by stability data, confirmed by sites.

The FMEA by sea freight describes the potential failure modes when transporting the product loads by sea. Process maps were again developed to identify and rank potential risks at each step. These outcomes were added into the FMEA results table and ranked by RPN. These findings were then investigated. Recommendations for risk reduction were made based on discussion with the evaluation team. No action was taken for low risks.

### ***FMEA by road freight***

LSPs provide temperature-controlled vehicles based on the product type (2-8°C for cold chain and 15-25°C for ambient). During road freight, data loggers are included for cold chain shipments as the products are sensitive to temperatures. Depending on the urgency of the order to be shipped, agreed incoterms and/or contractual arrangements with the distributors or warehouse facilities, the products can be shipped using one of the below shipping routes: Direct shipments (site to customer), Stopover at warehousing facility for consolidating orders/ repacking/ splitting orders before delivery to customer or Cross-docking before delivery to customer. The FMEA by road reviews potential failure modes during on-road transports using temperature-controlled vehicles.

Process maps were developed for road freight and risks assessed and ranked by RPN for the purpose of initiative actions to mitigate the risks of failure.

## **DISCUSSION**

### ***Air freight***

Air freight shipments of the products must follow the International Air Transport Association (IATA) Regulations. 18-step process was mapped from order placement to order delivered to the customer. The FMEA reports a number of risks. The top findings are:

- (i) Undetected temperature excursion (Medium risk score of 24) due to (a) Missing thermal blankets or pallets shippers, (b) Release of products without reading data loggers and (c) Incorrect shipping conditions used during transportation
- (ii) Delayed order (Medium risk score of 24) due to (a) Wrong order loaded on flight, (b) flight cancellation or delay in flight departure and (c) goods not cleared at customs or held up. It is vital to understand that if shipments are delayed, this can lead to potential quality impact as this may impact supply in market. As per contractual arrangements, customers are required to have a safety stock.

### **Sea freight**

Shipping companies must be in compliance with the International Maritime Organization (IMO) rules. The process map included 19 primary steps that start with the customer placing the order and end when the order is delivered to the customer. The FMEA reports a number of risks. The top findings are:

- (i) Potential contamination (Medium risk score of 24) due to (a) Dirty container or container not suitable for shipping pharmaceutical products
- (ii) Release products without reading data loggers (Medium risk score of 24)
- (iii) Incorrect shipping conditions used during transportation (Medium risk score of 24)

### **Road freight**

Road freight shipments, from and to destination site, must adhere to GDP and/or any other national guidelines and as per written. Here 18 process steps were identified from ordering of a shipment to final delivery. As part of the 14 risks, the most critical item was related to the incorrect shipping conditions used during delivery to customer. These include incorrect truck temperature before loading the goods, temperature excursions, variations in climatic zones (for instance from one country to another).

## **RECOMMENDATIONS**

Based on the findings of the risk assessment, the following recommendations have been made to Company X

Table 3 Recommendations

<b>Potential failure mode</b>	<b>Recommendations</b>
Missing thermal covers or pallets shippers	To update the technical agreement with ABO for packing cold chain orders into pallet shippers.
Wrong order loaded on flight	Proactive monitoring
Flight cancellation or delay in flight departure & Goods not cleared at customs or held up	More stringent SOP coordinated with the airlines
Flight cancellation or delay in flight departure	Better monitoring of flight status or delays
Flight cancellation or delay in flight departure	Alert program in place: Customer service reaction time is immediate

Release products without reading data loggers	Reinforce LSPs on the technical agreements
Incorrect shipping conditions used during transportation	AGI Logistics to provide LSPs an updated list of products with correct shipping conditions.
Dirty container or container not suitable for shipping pharmaceutical products	To include requirement to use CDOF containers in the technical agreement with LSPs

## CONCLUSION

Pharmaceutical products are time and temperature sensitive. It is a regulatory requirement to maintain the temperature of pharmaceutical products within acceptable limits during their distribution processes as stipulated by the national and international regulatory bodies. Company X must ensure that every activity within the supply chain process is compliant with GMP and GDP. Transportation is now seen as an extended storage during which a defined temperature regime should be safeguarded.

Company X has been receiving increasing complaints on temperature excursion for Australia Asia shipments during the past few years compared to other regions. The aim of the study was to identify and assess the risks during transportation of products from the manufacturing site to the final customer across this region through the application of quantitative Failure Mode and Effects Analysis (FMEA) and proposes actions in order to proactively mitigate failures during the shipment to preserve the quality, safety and efficacy of the products.

The FMEA revealed risks associated to temperature excursions, delayed orders and potential contaminations. Based on the RPN, the team recommended actions to reduce the medium risks to an acceptable level. No actions were required for low risks since good controls are already in place.

Based on the corrective actions, the team reassessed and rescored the severity, probability of occurrence and likelihood of detection for the top failure modes to determine the effectiveness of the corrective actions taken. The revised RPN scores indicate that the organization was able to reduce the risk associated through the performance of the FMEA and the implementation of corrective actions. It was also observed that the intensity of excursions has reduced from Aug 2015 to May 2016, with a noticeable shift towards the 'minor' classification. It is currently not possible to set an acceptable target limit for the number of complaints against the number of shipments as the business model is very dynamic and the inherited complexities of new deals.

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## **Session 5: Applications of ICT in Supply Chains**

# **Lean Management through Industry 4.0: Applicability to the Seven Types of Waste of the TPS System**

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## **Purpose:**

Industry 4.0 is a new approach that uses cyber physical systems and Internet of Things (IoT) to enable human-machine interaction in manufacturing industries. Unlike the implementation of traditional lean tools, companies tend to use smart systems more and more in order to realize benefits of their working environment. This paper investigates the ways in which Industry 4.0 (the implementation of smart systems) provides applicable tools for combatting seven types of waste. In addition, this research explores the application of these systems and how their impacts can be measured in the manufacturing environment.

## **Design/Methodology/Approach:**

At first we recall the seven types of waste, as they were introduced, determined and analysed in the traditional TPS (Toyota Production System), the cradle of the lean philosophy. In our age, several research papers focused on the field of Industry 4.0. Through transformation of traditional lean tools to the automation technology, the link can be perceived between Industry 4.0 and lean management. Our research will focus on future insights of Industry 4.0 methods as possible combatting tools of the seven waste in manufacturing industries.

## **Findings:**

In the light of literature regarding the subject, Industry 4.0 is capable of reducing the seven types of waste. Automated and smart systems drive the companies through leanness and efficient working environment.

## **Originality/Value:**

Little research exists on the subject of lean management and implementation of Industry 4.0; therefore, it is still questionable as to whether Industry 4.0 covers the requirements of lean management. This paper draws on different perspectives in regard to the seven types of waste and the future impacts gained through Industry 4.0.

**Key Words:** TPS System, Lean Manufacturing, Industry 4.0, smart systems, automation

## **INTRODUCTION:**

The wave of technology in using intelligent systems has accelerated nowadays; that means the integration of computer systems has become much more prevalent in the manufacturing world. Through the development of Information and Communication Systems (ICT), the transformation of traditional companies into the smart factories occurs by creating flexible and agile structures (Weyer et al, 2015) This in turn, encourages the collaboration of human and the intelligent systems. Besides, lean concepts are given much



more importance after considering the perceived advantages of creating the sustainable ambient. Living with the technological reality has an enormous effect on lean concepts, especially in decreasing the complexity of operations planning and service.

The desirable vision of the future is described by Zuehlke (2010) as achieving the lean technologies. Thanks to Industry 4.0, each of the service tasks would be determined by the interoperability of the networks and each of the devices pursues their own objectives in the system. Besides, IoT would enhance the open network among the intelligent systems to realize their own objectives. The Fourth Industrial Revolution considers the smart concepts and digitally enabled production by using embedded systems on integration of human and machine (Erol et al, 2016). The emerging technologies such as big data, IoT, cloud computing technologies coordinate with each other and create the framework of self organized reconfiguration; these are the backbone of creating the smart factory (Wang et al, 2016). Digitalization is becoming increasingly pervasive in smart factories.

Lean Management through Industry 4.0, is the future vision of the industries (Kolberg and Zühlke, 2015, Mrugalska and Wrywicka, 2017, Khanchanapong, 2014). Manufacturing environment enhances their operations via both waste reduction (greener) and work reduction (leaner) (Lee et al, 2013). In this paper, we mostly focus on work reduction by transforming TPS waste into usage through Industry 4.0. Our main objective of this research is to generate the modern TPS by using smart systems rather than traditional methods. As determined in the literature, companies still suffer to eradicate the seven deadly wastes on their shop-floors; therefore, in this research we discuss the ways of achieving lean management through Industry 4.0. Besides, we explore what kind of smart systems could be used in combatting seven types of waste and how to integrate them into SCM. The main contribution of this paper is to understand the applicability of Industry 4.0 over lean management and gives the insights of the conceptual framework of implementing Industry 4.0.

### **Research Methodology:**

This paper conducts a review of the lean management and Industry 4.0 by analyzing existing literature in databases includes Emerald Insight, Science Direct, IEEE Xplore and Google Scholar (the most cited articles on the field). A review of the literature examined reveals that the link could be perceived between lean wastes and Industry 4.0. It is a challenge to figure out a consistent review of perception between Industry 4.0 and each type of waste; therefore, each article have been examined in detail. The research concentrates on the journals in between 2003-2017 in order to not be contradicted in traditional TPS System. For search criteria, the several key words have been chosen related to the field; 'Industry 4.0, TPS, Lean Management, Smart Systems, Smart Factory, Seven Wastes, CPS and IoT. We identify the various papers on these key words; however, after all redundancies, around 83 papers have been examined from selected publication portals.

The paper is structured as follows. In the first phase, we define the causes of seven types of waste as put in literature and how they arise in the shop-floors. In the second phase, we define the Industry 4.0 through the nine dimensions which mostly describe the future vision of Industry 4.0. In last phase, we create the business model of integration of Industry 4.0 into the shop-floors as classifying the dimensions of Industry 4.0 into the three concepts; Smart Components, Cyber Physical Systems and Smart Networks.

### **Phase I: Causes of Seven types of Waste:**

Waste can be defined as activities that do not add value to the product as perceived by the customer. The lean concept is mostly described as seven types of waste derived from Toyota Production System. Womack and Jones (2003) have also added an eighth sort of waste by calling it as lacking of human talent or creativity. However, this type of waste is still debated on the literature; therefore, we did not include the eighth waste in our research.

The notion of waste could arise in lack of information infrastructure, appropriate, accurate and update information from the customers. The failures caused by the seven types of waste could identify demand factors. The concept of information value explicitly could be mapped identifiable on overprocessing, waiting, overproduction and defects when considering digital electronic system (Hicks, 2007). Rawabdeh (2005) argued that the seven wastes could affect each other and these relationships compound the impact of each waste type. Shaw and Blundell (2014) indicate that the causes of muda wastes could occur due to inadequate materials, processing or operational problems, systemic (external factors or management control problems) and poor knowledge and behavioral changes of humans as it is cited from Ishikawa fishbone. Fercoq et al (2016) address the issue that the managerial and performance controls on the processes would be reduced by the seven types of waste.

In the same vein as these articles mentioned above, we approach the issue of dividing the causes of the seven types of waste into two areas: a.) the causes arising in demand and b.) in management failures.

### **Phase II: Dimensions of Industry 4.0:**

In this phase, we define the dimensions of Industry 4.0 as defined in the same methodology of Boston Consulting Group (Rüßmann et al, 2015). As checked in literature, we structure the dimensions as nine pillars.

#### **Big Data:**

Big Data allows us to quickly and efficiently manage and use a constantly growing database. Big Data would be applied to provide the necessary database and required performance. The firm could give the tactical decisions, and extension of decision database could make the potential savings and stay in competitive advantage through all supply chain. Countless decisions are performed by control systems, humans and CPS Managing by Big Data issues gives an advantage of fault prediction, demand forecasting of customers (Ji and Wang, 2017) and creating cleaner production systems (Zhang et al, 2017).

#### **IoT:**

An IoT system is capable of managing the integration between shop floors and the data taken by customers. The specific products could be created by customers and via web servers, the data is transmitted to the industrial clouds. The data received provides the information about customer demands; therefore, the manufacturer will integrate design, and will optimize, manage, and monitor the production process due to produce products efficiently (Lu, 2017). Technically speaking, the IoT comprises of physical artifacts that have the ability of electrical, mechanical, computing and communication through Internet data exchange.

#### **Cloud Computing (CC):**

Cloud systems allow for a shared platform of diversified Supply Chain, where exploit demand access, creating efficiency, optimizing resource allocation in response to different customer demands. Therefore, the characteristics of cloud based systems generate agile, unlimited access by shared information through partners, virtualization, resource pooling and everything as service (Thames and Schaefer, 2016). Smara et al (2017) carried out the study on Cloud Computing Systems to develop the aspect of resistance on errors or mistakes; therefore, it presented the fault detection component on Cloud systems. For cloud, any systems can be optimized to create predictive workload information on realistic system. A condition monitoring layout through IoT and CC is applied for process monitoring in evaluating system performance, detecting system failure and estimating system health status by using the opportunities of IoT (Xia et al, 2016).

**Augmented Reality:**

Augmented Reality (AR) technology derived from the interaction of human and computer as wearable devices as well as the regular interaction such as voice, gestures, tactile and visual. Augmented Reality technology is based on the relevant information provided by the smart components attached to human. The performed tasks are visualized and animations overlaid on demonstrator. By using this technology, the time is utilized by reducing wasteful activities; by doing so, tasks could be performed with minimum errors, enhancing maintenance efficiency and less time required to achieve the same tasks of maintenance. (Erkoyuncu et al, 2017).

**Additive Manufacturing:**

Additive manufacturing technology, mostly known as 3D printing, allows for value creation processes and business models of Supply Chains based on customer centric logic. 3D machines are simply conducted in optimizing the production layouts and offering process accuracy. Besides, new business models creates the innovation driven models and balance the activities of process held by manufacturers and the individual needs of the customers (Bogers et al, 2016).

**Autonomous Robots:**

Autonomous robots collaborate with humans in a working environment due to the ease of the tasks, reducing human errors and implement the efficiencies in process flow. The planned tasks could be pursued by robots and each complex scenarios are operated as reducing non value added activities (Muñoz et al, 2016). Technological means foster the ability and capability of the robots as enabling the robustness of the process flow and their optimized ability is able to reduce the unnecessary activities and completion time of the process and enable to solve the complex tasks (Carnevale, 2016).

**Simulation:**

Simulation and mathematical algorithms approach business models and design optimization in industries by using the computational level of embedded systems; through the data received from external drivers based on the experiences or customer centric driven, simulation models convert the data into the meaningful information could be done by industries by calculating the optimum level of each activities and overall system (Greinacher et al, 2016).

**Vertical and Horizontal Integration:**

Due to lack of integration of IT systems, either the supply chain partners or the departments in shop-floor level are not integrated. However, through the evolution of Industry 4.0, the departments, functions and capabilities would be much more adherent and data transmission would be available between fully integrated SC partners. (Rüßmann et al, 2015). The complex tasks could be manageable via cloud systems (shared platforms) and all the data could be taken via partners such products and process information, inventory level, shipments and so on.

**Cyber Security:**

The security concerns are a controversial subject after the evolution of Industry 4.0 due to the prevalence of cyber attacks. It is necessary to ensure that the system is secure without disrupting the real time operations and performed tasks. Therefore, it is important to run robust mechanisms in operations without data leakage and destruction of privacy aspects (Ashibani and Mahmoud, 2017).

### **Phase III: Classification of Dimensions of Industry 4.0**

In this phase, we attempt to create the new business model in case of the integration of Industry 4.0 into the shop-floors; therefore, we categorize those nine pillars into the three dimensions; smart components, cyber physical systems, and smart network. Smart components comprise the physical components that maintain the operations and management activities; Cyber Physical Systems (CPS) create the virtual world over those physical components by giving the ability of computation, communication, configuration and human integration into the process. Finally, smart network achieves the integration of various partners in Supply Chain into the process through Internet due to create more visible, accurate and responsive SCs.

#### **1. Smart Components:**

##### **Auto-ID and Sensor Technology:**

Smart components interact with each other through the data transformed by sensor technology. Auto ID and Sensor Technology have the immense effect of monitoring and tracking the products in real time. Auto ID, of which the mostly known example is RFID, is the quick and safe way of tracking the products and providing the accuracy on real time information management. By Auto ID technology, the product process flow could be visible in better way and the information flow in shop-floors could be achieved in fastest way by reducing lead and capture time as well as managing the inventory level as controlling the products produced. (Klein, 2009). The real time traceability offers the system on better planning, scheduling and control decisions and product information for up level. (Zhang et al, 2015). Ramadan et al (2016) found the RFID technology could be applied in every kind of lean tools by reducing wastes in different percentages such as 5S, ANDON, TPM, STANDARD WORK, SMED, and POKA YOKE by transmitting automated data collection, adherence to independent data and improvement in visible controls. By using RFID tags and scanning devices, more precise demand could be proceeded by less manual interactions. Inventory levels are calculated automatically by autonomous systems by only less interactions of human (Hofmann and Rüscher, 2017).

##### **GPS Technology:**

GPS technology is also mostly used in navigating of the vehicles and routing guidance GPS plays the complementary role of vision driven systems by detecting the incidents without intervention of human operators. Besides, they provide the real time information; therefore the vehicles could be traced and tracked easily (Zhang et al, 2011).

**Intelligent Control Units: HMI** (Human Machine Interface) and **PLC controllers:** These programming systems comprises various communication and subsystems that predict the failures in the system (Priyadharson et al, 2015). The accurate software systems could be used with HMI due to the optimization of the processes and take the accurate data in real time basis. HMI based shop-floors perform in controlling the tasks and monitoring the system. Thanks to the visualization commands, operational teams could diagnose technical errors, having better process controls and solving the problems based on the delays on the process and help the malfunction and maintenance activities (Panda et al, 2016). This enables quick reaction to problems and facilitates monitoring the shipping and transportation activities (Salihbegovic et al, 2009).

##### **Additive Manufacturing Machines:**

Additive Manufacturing Technologies consist of both novel 3D printing and the more conventional digitally controlled machines. The product centric control develops the resource efficiency by simplifying control and customization solutions make possible in

producing by small batches as reducing inventory and overproduction and creating optimization on processes (Lyly-Yrjänäinen et al, 2016). Additive systems optimize the process as precluding the overusage of materials and WIP inventory by controlling the product process flow (Jared et al, 2017).

### **Automated Guided Vehicle:**

Automated Guided Vehicles (AGVs) are used in moving tasks, loading and checking the items and finishing the tasks. The information systems transform the moving tasks into the AGVs; also RFID readers attached to the AGVs could receive the signals from the tags to know the current location sites of the products. According to the tags, even AGVs have the information about the quantity of the items prepared or not and which items should be loaded into the which sites; therefore, they can be used as the trace and tracking components as well (Zhang et al, 2015).

## **2. Cyber Physical Systems (CPS):**

Cyber Physical Systems can be considered that combine the physical and virtual world together through the Internet. Simply, it could be defined as the computational level of the physical processes. The integration of CPS includes 5 level architecture from data acquisition to the value creation; these are smart connection, data conversion to information, cyber level, cognition and configuration level (Lee et al, 2015).

By their computed capability, they could be used as the fault detection, Plug and Produce system makes the set up reduction possible on Smart Factories (SMED Principle) (Kolberg and Zühlke, 2015). Automated assembly lines would enable the physical and virtual parts work accurately and implement lean principles in Smart Factories (Zuehlke, 2010). Embedded systems could optimize and control the processes with feedback loops. Therefore, the synchronised systems could communicate with each other and interconnected with each other by network structure. These systems could predict the inventory and control the production levels, visualizing the process tools, detect the waiting objects and predict the machine health as their computational and communicational level (Mrugalska and Wrywicka, 2017).

## **3. Smart Networks:**

Technological aspects impacting Supply Chains in the path of digitalization, are creating more visible and flexible planning and controlling the operations; by doing so, many challenges have been overcome in terms of better predicting customer demand, increasing efficiencies, reducing costs, increasing flexibility and reducing the lead time (Merlino and Spröge, 2017). With the help of cloud solutions, better integrated supply chains could be found; this has led to improvements in storage management by getting more reliable data in inventory, real-time interconnection of raw materials, product information and process flows (Bruque-Camara et al, 2016). Besides, intelligent transportation systems support the cloud and dynamic systems by enabling vehicle routing and allocation of the demands, parking systems, communication between vehicles through VANET network due to increase reliability, optimization and safety concerns on SCs (He et al, 2014).

As reference to our literature based work, we classify the dimensions of Industry 4.0 as smart component, CPS and smart network in terms of operability of lean management and reducing seven types of waste. The summary of our findings are illustrated in Table 1.

**Table 1. Examples of Reducing Waste (of Lean) through Industry 4.0**

<b>Lean/Industry 4.0</b>	<b>Smart Components</b>	<b>Cyber Systems</b>	<b>Physical Smart Network</b>
<b>Overproduction</b>	Auto-ID, Intelligent Control Units, Additive Manufacturing Machines	A CPS to predict production plan's implementation	Networked production control and integrated SCM
<b>Waiting</b>	Automated Assembly Line, Auto-ID, AM machines	A CPS to detect, awaiting objects	Networked operators and process control
<b>Transport</b>	Track and trace(GPS, Sensor,), Auto-ID, HMI, Automated Guided Vehicles	A CPS to plan dynamic rerouting and parking systems  A CPS to align the layout to the demands	Networked vehicles and SCM Intelligent Transportation Systems  Through VANET Network, enables V2V and V2I communication
<b>Overprocessing</b>	Augmented Reality Devices, Intelligent control units, Auto-ID	Things are visualized by smart devices and every process are known by each employee for their certain tasks  Process analyzing tools	Cloud solutions for Process analyzing tools
<b>Inventory</b>	Auto-ID, Additive Manufacturing Machines	A CPS to forecast inventory	Networked SC participants
<b>Motion</b>	AR and AM devices, autonomous robots, Automated Guided Vehicles	Process analyzing tools	Cloud solutions for Process analyzing tools
<b>Defects</b>	Sensors, Automated Assembly Line, Auto-ID, Intelligent Control Units	A CPS to predict future machine wear	Predictive Maintenance machines and personal networked repair

*Source: own elaboration*

### **Conclusion:**

This paper gives insights about the operatibility of lean (seven types of wastes) through Industry 4.0 technologies in terms of smart components, CPS and Smart Network. Our findings provide a compelling message that Industry 4.0 will bring the future evolution of those wastes on the way of digitalization and all types of wastes could be manageable more than it is perceived now. Our work addresses the issue of the causes that trigger the waste and non value added activities that could be eliminated by better forecasting on demand and management controls such as achieving real time data thanks to digitalization. In future work, these wastes could be extended by exploring the impact of being greener and different aspects that caused the wastes could be explored.

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Due to the page limitation, the whole reference list could not be added to the reference part. A complete reference list can be available from the authors upon request.

# **SUSTAINABLE SUPPLY CHAINS IN THE WORLD OF INDUSTRY 4.0**

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## **Purpose**

Industry 4.0 introduces a series of changes for the supply chain, in particular in terms of technology, structure, connectivity and communication. The sustainable aspect in Industry 4.0 needs to be highly correlated with digitization at a process, product and organizational level (*Reichel, 2017*). This paper presents a framework for the implementation of sustainable solutions along digitally integrated supply chains.

## **Design**

Firstly, the paper presents a structured literature. Secondly, results of the survey performed to different industrial sectors in Europe are discussed and interpreted. Thirdly, the paper presents a guideline and a dynamic framework for companies to implement sustainability along the supply chain when implementing Industry 4.0.

## **Findings**

In Industry 4.0 information plays an important role for clustering processes, involving the supply chain in the whole life cycle processes (*Prause, 2015*). Companies are interested to create awareness in restructuring processes to account for increased sustainability goals while they are already being restructured to allow for Industry 4.0 technologies. However, most companies lack the overview to do so and previous research do not provide a comprehensive framework on the sustainability trend inherit in Industry 4.0.

## **Value**

This paper provides a dynamic and applicable framework studied and developed according to organizational needs. The framework drives companies to implement digital solutions able to monitor emissions along the supply chain, based on relevant aspects of the 17 Sustainable Development Goals (*UN, 2015*).

## **Implications**

The framework can be used as an operational tool for companies implementing Industry 4.0 trends in terms of sustainability considerations. It is meant as a strategic guide to help decision-makers implementing Industry 4.0 technologies to do so with a sustainable perspective in mind. This allows companies to see the changes from a holistic perspective, considering People, Planet and Profits and creating a long-term competitive advantage.

## **INTRODUCTION**

Globalization is changing industrial processes and has requested sustainable requirements to the modern Supply Chain, due to environmental changes, regulatory needs and increasing demand in quality and quantity (*Manzini, Bozer, & Heragu, 2015*). Industries are currently entering the fourth industrial revolution, where processes along the supply chain become digitized. This digitalization and interconnectivity give companies more opportunities to increase production and revenue. However, horizontal and vertical supply chains have to be effectively integrated in order to obtain a totally automatic value chain, from the supplier to the customer (*Colotla, et al., 2016*). This will



imply several changes in the company's product and portfolio management and need for new alignments in the organization. It is predicted that in the next five years, 85 percent of all companies will have implemented digital, internet-based and integral solutions (Geissbauer, Schrauf, Koch, & Kuge, December 2014). A digital business model can give the opportunity to customize solutions, satisfy customers and create competitive advantage (Stiel & Teuteberg, 2015). However, the investment required for implementing Industry 4.0 solutions is often large and several constraints have to be considered, such as needs of qualified personnel with know-how on embedded systems and costly supply chain processes (MacDougall, 2014).

Digital processes, robotics and big data analytics can, if established successfully, ease the supply chain. However, this does not automatically mean a more sustainable supply chain is created, as Industry 4.0 trends so far have lacked a sustainability aspect. The research question this paper seeks to address is therefore *"How can companies use one common framework to integrate their supply chain, digitally, while keeping a minimum environmental footprint?"*

## **LITERATURE REVIEW**

### **Vision and Mission of Industry 4.0**

The third Industrial Revolution, started around 1970s, was based on developing advanced automation in manufacturing through electronics and information technologies (Acatech, 2013). This led the foundation for the fourth one, where people, things and machines are interconnected in a complex system, called "Internet of Things". The heart of Industry 4.0 is the creation of smart factories, smart products and services, smart machines, smart storage and smart supply chains (Kagermann, Lukas, & Wahlster, 2015). Smart products are able to self-organize their production process and flow through smart data; where the material flow of the product life cycle will be conducted by smart logistics solutions (Stock & Seliger, 2016). This connection of physical operations with computing and communication infrastructure is enabled by Cyber Physical Systems (CPS) (Jazdi, 2014). It can be applied to medical equipment, automobiles, industrial processes and automation systems (Yu & Fei Xie, 2013) and more important for this research, to industrial systems for monitoring optimum power supplies in terms of renewable resources (Jazdi, 2014). CPS devices can be placed everywhere, even underwater, this potential has to be exploited for environmental goals (Estevez & Wu, 2017). Green CPSs can handle and send environmentally tailored data to other technological devices, ensuring a sustainable development.

When looking at the frame of Industry 4.0 it is possible to identify three different levels (Stock & Seliger, 2016): horizontal integration that represents company intelligent cross-linking and digitalization of the whole value creation network, through the value chain of products life cycle; end-to-end engineering that represents the intelligent cross linking and digitalization across all phases of a product life cycle; vertical integration and networked manufacturing systems that represents the intelligent cross-linking and digitalization at the different hierarchical levels of the value chain (Acatech, 2015).

### **Sustainable Development**

The original definition of Sustainability is from the Brundtland Commission where it is defined as *"...development that meets the needs of the present without compromising the ability of future generations to meet their own needs"* (Commission, 1987). In the past people thought natural resources were infinite, on the contrary, today, it is fundamental to realize that resources are finite in order to move toward a sustainable development (Mulder, 2006), defining challenges and goals for the future of the planet. Sustainable development aims to decrease or eliminate differences between poor and rich, current and future generations, humankind and nature (Mulder, *Sustainable Development for Engineers*, 2006). Production processes and corporate interests should be reviewed, improved and changed for a green business development.

Environmental, social and economic problems have been collected into a global program of Sustainable Development Goals (SDGs) coined at the United Nations Conference on Sustainable Development (UNDP, 2012). It addresses 17 sustainable goals and 169

targets to achieve before 2030. Goal 12 specifically addresses corporations: “Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle” (UN, 2015).

### **Corporate Sustainability**

Corporations have a central role on environmental impact and the need to embed sustainable actions within their systems and processes (Lonzano, 2012). Corporate Sustainability creates long term values integrating TBL within culture, strategy, decision making and operations of organization (Linnenluecke & Griffiths, 2010) and it challenges companies on improving social and human well-being while minimizing the environmental impact and reaching organizational goals (S. Sharma, 2003). For obtaining sustainable industrial practices, the focus based on relative improvements should move toward absolute assessment of performance (Hauschild M. Z., 2015), broadening the economic aspect to social and environmental dimensions. Companies should understand that their incomes are proportional to the value they create for the society (Mulder, 2006) and that Corporate Sustainability is an added value for the corporate image (Zhu, Sarkis, Cordeiro, & Lai, 2008). Companies can improve eco-efficiency and eco-effectiveness (Hauschild M. Z., 2015) with Cradle to Cradle, which contains the principle of “waste equal food”. It is based on developing a good design for minimizing wastes and environmental impact of physical product and processes emissions (Hauschild M. Z., 2015).

### **Sustainable Supply Chain**

Sustainable Development has demonstrated high impact on businesses, operations and their supply chains (Boone, Jayaraman, & Ganeshan, 2012). Sustainable Supply Chain can be defined as the management of physical goods, information and capital flows, where companies cooperate along the supply chain basing their businesses on the three pillars of sustainability, or TBL: economic, environmental and social (Elkington, 2002). The set of managerial practices based on environmental impact and the entire product life cycle is called Sustainable Supply Chain Management (SSCM) (Gupta & Palsule-Desai, 2011). In SSCM, companies are using environmental-sensitive design, re-designing products for their circular life cycle (Boone, Jayaraman, & Ganeshan, 2012). Furthermore, Industry 4.0 provides high flexibility through modularity, enhancing fast adaption to changes. Digital communication with suppliers enhance make-to-order, decreasing inventory, lead times, resources and emissions (Gilchrist, 2016).

### **The Role of Technology**

Technologies have a fundamental role in Sustainable Development. The extent to which it influences the environmental impact  $I$ , is represented through the formula IPAT (Holdren & Ehrlich, 1971), consisting of three factors: Population ( $P$ ), Affluence ( $A$ ), which is the Gross Domestic Product per person, and the Technology factor ( $T$ ). The formula is the relationship between:  $I = P \times A \times T$  (1). In the equation,  $T$  is also called ‘Technology efficiency’ (Mulder, 2006).  $T$  decreases when the technology efficiency increases, which should cover the whole products life. Eco-efficiency ( $1/T$ ) can be measured by the Life Cycle Assessment, according to ISO Standards (Hauschild M. Z., 2015). Hence digitalization and new technologies should decrease the  $T$  factor, knowing that technology efficiency in 2050 has to be 32.4 times more efficient than in 2000 (Mulder, 2006).

### **THE CHALLENGE**

The trends driven by CPS that influences Industry 4.0 the most are: Additive Manufacturing, Simulation, Horizontal/Vertical Integration, Industrial Internet of Things, Cyber-security, Cloud, Advanced robots, augmented reality, Big Data and Analytics (Colotla, et al., 2016). Unfortunately, Industry 4.0 does not address sustainable problems. This gap can be fulfilled through introduction of sustainable solutions, such as green CPS and general data monitoring under environmental measures. This research aims to fill this gap at each step of supply chains.

## METHODOLOGY AND RESEARCH WORK

The data for this research was collected through a structured literature review and empirical data in the form of a survey. The online survey was sent to employees with a good understanding of their company's supply chain due to their position in the company. It was structured in four main parts: information, degree of sustainability, degree of digitalization, maturity of the company to assess the type of change to adopt and conclusions for further information on the research. Based on the results from the survey, coupled with the structured literature review, a model of how CPSs and IoT can be used to monitor Supply Chains through digital integration, in order to achieve the SDGs, has been developed. Lastly, theories of change management, companies' maturity in green solution and industry 4.0 outlined in the survey and drivers for corporate sustainability, have been analysed and connected into a framework based on Kotter's 8 steps of change management.

## RESULTS

Most of the respondents of the survey were managers from pharmaceuticals, chemical, medical, telecommunication, IT, electric, biogas, controls and food companies. 35,7% were large companies, 35,7% were small-medium sized and the remaining 28,6 % small. The companies operate worldwide and 85,7% have a highly complex supply chain, in terms of numerousness, variety and interconnections of operations and processes. What is surprising is that for 64,3% of companies' sustainability is very important, but the extent to which green solutions are implemented along the supply chain is lower. Regarding digitalization, 28,6 % has already integrated digital processes, while 57,1 % is investigating it. The 28,6 % of the companies is already part of the UN Global Compact and the Core business of the 42,9% is based on the TBL. Even if this is very positive, the other 57,1% of the respondents is still lacking a green business approach. Some enterprises are following some of the SDGs but it was restricted due to a lack of economic benefits.

## ANALYSIS

Based on the literature review and the empirical data Figure 1 has been developed. The figure shows a picture of how ideally the supply chain could be monitored using IoT with end to end digital integration for its operations and processes. They should be controlled



Figure 1: The Cloud Monitoring Supply Chain processes by SDKPIs

by Sustainable Development Key Performance Indicators (SDKPIs), reporting on consumption and emissions, toward a fully accomplishment of the SDGs in 2030. The focus in Figure 1 is on the sustainable digital supply chain layer. The general explanation, starting from the top-left is that companies have to provide: vertical digital integration connecting the supply chain layer with the others, such as Sales & Marketing, HR, etc. (Stock & Seliger, 2016), horizontal integration across the activities of each layer and end to end

digital integration along each value chain. The shape of this model is circular because it is based on green supply chain management, which is the integration of the environmental thinking with SCM (China, Tatb, & Sulaimana, 2015). The central position given from IoT systems is similar to previous research, in particular the macro-perspective framework

(Stock & Seliger, 2016). With materials being traceable from an early stage until the end of their life, it is possible to monitor data and improve them over time. This allows companies to act on water sanitation, energy reduction, economic growth, industry innovation, developing a more sustainable community, reducing CO2 emission and GHG, acting on climate change, saving the life below water and on land and increasing partnership with stakeholders. Moreover, the United Nation has created an Industrial Matrix, where companies can see how to act better on each SDG (UN & KPMG, 2016).

## FRAMEWORK FOR CHANGE

Companies highlighted various needs to start or complete the Sustainable Journey (Kohl, 2016) throughout the survey. It is a compelling change and they need to define at which level of the Sustainable path they are. The first level is Exposure: set of baseline indicators, building efficiency and compliance projects. The second is Integration: including sustainability in business processes, cross functional and stakeholder engagement, reporting assessments. The third and last one is Transformation, when sustainability becomes part of the core strategic vision of the company, being part of decisions, culture and processes. To give companies a chance to reach the peak of the change with a complete Transformation, a fast and agile model for changing is addressed.

The model is based on Kotter's 8 steps Change Model (International, 2017), the actions taken should be both bottom up for creating a common vision and top down for defining strategies. The model is here combined with Sustainable Goals and ISO-14000 norms. The framework contains eight steps companies should imitate to plan carefully and to create a solid foundation for the change. Repeating the stages over time can accelerate the process of transformation and make the organization more robust thanks to engagement of people and attention paid by stakeholders.

Table 1 : 8 steps of Change Model for Sustainable Supply Chains in Industry 4.0.

<b>STEP</b>	<b>DESCRIPTION</b>	<b>PRACTICE</b>
1. Create sense of Urgency	Identify threats and green opportunities. Develop scenarios for the long and short term. Ask support to stakeholders.	Identify new product design for ease reuse and recycle. Search Sustainable standard applicable to your company. Understand how to connect IoT to the SC for monitoring data.
2. Build guiding coalition	Set a group of engaged people to guide the activities and sustaining the change.	Identify the impact areas of the SC. Address SDGs and find right tools for the environmental assessment in the value chain (i.e.: GHG Protocol Scope 3 Evaluator, WBCSD Global Water Tool, etc. (UN Global Compact, 2015))
3. Form a strategic Vision for change	Determine green values and strategies. Implement the change from small scale (pilot).	Implement ISO-14000 standards. Use LCA, environmental measurements, on small pilots, with Green CPSs.
4. Communicate the Vision	Communicate positive results. Share the green mission at the operational level.	Show good results and positive KPIs from the pilots. Communicate the success to the company, engaging more people.
5. Enable action by removing barriers	Identify a good change leader and align organisational structure. Use reward systems.	Remove barriers between digital and green business. Try to make the process agile, smooth software communication. Reward change supporters.
6. Generate short term wins	Reach small sustainable targets. Choose norms easy to reach in the short	Communicate the success. Show environmental, social, economic benefits with internal and external

	and long term.	stakeholders.
7. Build on the Change	Analyse what went well and what needs improvements. Set new goals. Try to achieve long term change.	See data monitored and where to improve them. Include all the SDGs in the long term. Have a fully digital and reliable control.
8. Institute change	Change should be applied at each level of the organization.	Green and digital businesses are perfectly aligned. Emissions are minimised and the pattern toward SDGs is very positive.

Most of the companies from the survey conducted during this research study needs to create the need for change, even if they are already sustainable to a certain level. This is because the coalition and the vision should be stronger. The type of change the organizations would adopt are mainly of three types (Hayes, 2014). 28,6 % of responding companies needs to have a Tuning pattern, incremental change for defining a better strategic vision. 35,7% of the companies who responded to the survey need Adaptation change to handle the external pressure, and do better on the sustainability goals the company is already addressing. 28,6% needs Re-orientation, a transformational change that involves a redefinition of enterprise, looking into future opportunities and problems. None of the companies need Re-Creation, which is based on total change of all its elements. This result is positive because it means that companies already have a good basis for being sustainable and digital but needs a good re-orientation and good management practices to guide the change.

Finalising what is needed to succeed with the proposed framework, in order to reach Green Business Operations, companies should operate following ISO-14000 environmental management standards (ISO, 2015).

## CONCLUSIONS AND NOTES FOR FURTHER RESEARCH

This research has been performed for creating a framework based on environmental emissions issues along the supply chain, thanks to digital integration. The framework offers a new and dynamic approach of change management that embraces the full transformation of the company, providing the possibility to start from pilot projects and test them overtime. For the first time, sustainable goals are considered as integral part of Industry 4.0 trends. The model addresses technical solutions (digital and environmental standards) within a holistic approach that are easy to understand and implement.

This paper lays the foundation for future research which should consider the practical implementation of the framework. Tested on companies having at least a digital part of their supply chain where the model can be tested, assessing numerically environmental footprint reduction and potential organizational benefits. Limitations to consider are that different industries may need different solutions and provide variable results.

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# ON THE INTEGRATION OF INTELLIGENT LOGISTICS ECOSYSTEMS IN PRODUCTION AND INDUSTRY 4.0 SETTINGS

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## ABSTRACT

In this paper, we describe trends in supply chain management as well as production and lay out what emerging technologies are enabling these fields. In the upcoming years, the challenge for the sectors will be the combination of cyber-physical systems both from the machinery of the production line as well as the supply chain. The way to achieve this goal is the integration of data and local intelligence using smart local devices with decentralised decision making, whereas advanced IoT technologies are a key enabler. This paper gives an introduction into emerging technologies, shows how organisation borders can be crossed, and finally describes how to use Industry 4.0 approaches in logistics service ecosystems.

## INTRODUCTION

The trends of the logistics and production industry of the recent two decades foresee the intelligent and smart integration of proven, data-driven lean and agile requirements of dynamic re-routing, tracking and tracing, multi-modal chains, and predictive (re-)routing. However, these concepts – whilst largely focusing on an integrated view of the whole supply chain – usually focus on logistics, leaving out significant requirements of the production and manufacturing viewpoint. With the advent of the recent Industry 4.0 movement, data integration is now also driven alongside the production line, mainly made possible by taking established concepts of smart supply chains, like the digital avatar used in holistic systems for intelligent transport eco-systems or the use of big data and artificial intelligence technologies intertwined with the modern supply chain. The purpose of this paper is to describe how data from the smart and intelligent supply chains – as for example described in [1] or [2] – can be integrated with Industry 4.0 data eco-systems (cmp. [3]). The technological key drivers for this topic are mainly the integration of data from ERP systems as well as legacy systems, the Internet of Things – including Smart Dust, RFID, web services and intelligent sensors attached to goods and or cargo items. Thus, the when considering smart industrial production in combination with intelligent logistics along the whole supply chain the following challenges and key questions must be addressed:

- How to design cross-sectorial context information for logistics and production (where, when is the data stored and processed)
- How to build automated knowledge of business services and underlying business processes
- How to incorporate the emerging self-awareness of individual goods or items, ranging from product sets (material lists, part lists, configuration descriptions) over intelligence for finding (re-)routing decisions to ad-hoc cross-company ICT communication design



- How to build automatically networks of trust (either via yellow pages for legacy systems or via block chain technologies) to ensure that smart avatars of goods/items can communicate across company borders and in real-time
- How to include established industry standards for data exchange in manufacturing settings, e.g. STEP, STEP-XML, EPC Global standards, and others
- How standardised product avatars can help to describe supply chain tasks as well as manufacturing tasks, ranging from transport and parts acquisition over manufacturing to recycling

This paper is intended a position paper that shows different possibilities to achieve the above-mentioned goals and propose technological and design methodologies, especially for data integration in heterogeneous environments. The described approaches are not meant to be definite industry standards, but rather show how trends from intelligent supply chains can be integrated into Industry 4.0 endeavours from an ICT point of view.

As a result, the paper is intended to address a number of challenges. The future modern, smart supply chain must deal with the a plethora of standards used in the manufacturing field, handle knowledge technologies (semantics, software agents), include ambient intelligence (service identification, item discovery, etc.), servitization of products, as well as provide benefits for customers from social and business cultural aspects.

The key findings of the paper can be seen as a basis for further discussion built upon the beforehand mentioned requirements and comparison to established and proposed data exchange designs, show future challenges, and provide background on how to integrate the proposed changes into day to day business.

## **LOGISTICS AND INDUSTRY 4.0 IN THE HEAT OF EMERGING TECHNOLOGIES**

In 2014 the Chief Executive Officer John Chambers of the networking hardware supplier Cisco Systems famously stated that the Internet of Things (IoT) is a 19 trillion-dollar opportunity [4]. Cisco has even extended the IoT vision to the Internet of Everything, thus having a more holistic approach to the mere technical viewpoints of IoT by including the people and surroundings – from consumers to citizens-, and products to (business) processes. For Cisco the goal hereby seems to be obvious, namely to delve into new markets after declining sales in their hardware sector. For the industry of the European Union the 19 trillion-dollar opportunity also exists, but solid ground work and key innovation leaders are needed in order to exploit the huge opportunities ahead. Basic work has already been accomplished by European policy makers and researchers. The European Commission's (EC) Digital Agenda is the policy framework under which future endeavours in the IoT field may find a flourishing ecosystem, especially when considering the Digital Agenda's focus on the call for a Digital Single Market, consolidating online trust and security, as well as leveraging smart use of technology for society [5].

With the FIWARE programme the EC has already supported the uptake and research for promising Future Internet technologies, whereas the last phase of the programme was particularly successful when it co-funded almost 1.000 SMEs and start-ups, many of them developing innovative solutions and services with IoT support. Awarding targeted funding for intelligent production, logistics and supply chain management was a key pillar of the programme. A numerous portion of the funded start-ups had smart production and logistics as topics in their business plans, either as their core plan or partially as business opportunities for their tools and/or services. It is also noteworthy that many of the solutions created by start-ups are not limited to an older view of IoT, but include holistic approaches where IoT is combined with the Cloud and Big Data. The support action FI-IMPACT which measured the impact of the programme showed that the resulting ecosystem "that makes up the [start-up] IoT market is both vast and complex, including modules/devices, connectivity, IoT purpose-built platforms, storage, servers, security, analytics software, IT services from consulting to on-going management of the solutions, and of course security" . FI-IMPACT also found that almost one third of all funded start-ups are developing IoT enabled products in one way or the other [6].

With the ARTEMIS joint undertaking project CRYSTAL the EC funded an initiative that targets the interoperability of safety-critical solutions in various application domains. With SOFIA, middleware has been developed for IoT architectures that is currently actively exploited and marketed by the Spanish information systems company Indra Sistemas under the name SOFIA2.

From the above cases, we can see that the seed for IoT and other smart technologies in Europe has been spread from a technological as well as a business point of view. However, a plethora of challenges still exist.

One core challenge is technological federation, i.e. ensuring that the multitude of (IoT) providers and users are interconnected. The interconnection is not only a technological challenge but also an organisational one. Currently, IoT solutions may be found in SmartCities - in the form of sensors and decision making support, in home devices - in the form of Smart Homes or energy monitoring, in health appliances for environment monitoring, in Smart Banking - in the form of mobile payment integration, in goods and people transport sector for track and tracing purposes, in Smart Retailing for marketing and goods surveillance measures, or in Smart Tourism for decisions making and entertainment purposes. All these solutions consist of devices, sensors and – if applicable – actuators. Nevertheless, as customised solutions have been built for all these areas, it resulted in systems where ‘things’ cannot discover and connect to each other as soon as they want to break out of their particular domain. This is a key challenge when combining multiple interconnected supply chains with many shippers, logistics service providers, transport planners, and others. As soon as the ‘thing’ furthermore needs to be integrated in an Industry 4.0 setting, where the data is used for intelligent manufacturing, work-place improvement, and production scheduling optimisation, the thing must bridge from one additional domain (shipping) into another domain (production) back to its originating domain (shipping). The smooth handling of the automated bridging of domain borders in a secure, smooth and sustainable way is the key challenge in combining efforts from the Industry 4.0 movement with logistics.

As an example you might consider a good in a supermarket attached to two separate IoT domains; firstly, to the logistics provider’s IoT system and, secondly, to the supermarket’s own in-house IoT system. Whereas both domains need the same kind of data and sensors, e.g. best-before-date or temperature sensors, closed IoT systems here result in duplication of sensors, data, and most importantly hardware. Here, IoT Federation comes into place by offering ways to interconnect existing resources between domains and technological data realms.

Another key challenge for current IoT architectures is the unique addressability of ‘things’ since a number of standards and approaches exist. Auto-ID Center is used for RFID tags, EPC code finally resulted in the use of IP addresses and/or URIs, the IETF extended the later with Semantic Web functionality, and GS1/EPCglobal’s EPCIS specification is used mainly for industrial settings. The list can be extended at will with lesser known standards, for example with the U.S. FDA UDI standard for medical equipment, or the OCF (Open Connectivity Foundation).

Other considerably significant challenges are privacy and security concerns related to IoT. When making devices, data, sensors, and potentially actuators of a ‘thing’ available across domains and institutional levels, appropriate anonymization of data must take place. Additionally, end-to-end security, identity and access management, as well as deployment and update policies need to be provided for holistic approaches in dynamic and scalable ways. This is especially true when considering the recent events where botnets consisting of IoT devices were used to drive Distributed Denial of Service attacks (DDoS) against major websites [7]. Secure and anonymised IoT architectures are a key driver for Open Data and innovative business solutions.

As a final challenge new solutions must differentiate between local and aggregated intelligence, thus distinguish between smart devices and mere (data) objects. In current set-ups the core intelligence is almost always handled on the server side, whether it be in the Cloud or in the back office. With the advent of powerful mobile processors this need not be case. Intelligence can be handled within a 'thing' thus also making it fail-safe if Internet connections get slow or break-down. In the ultimate vision 'things' can therefore create an emergent intelligence based upon emergent smart networks – via creating ad-hoc groups of 'things' - and emergent smart behaviour – via combining local computing resources.

## CROSSING ORGANISATION VIEWS

The last two decades showed a tremendous triumphal march of Supply Chain Networks especially for international economies and transnational businesses. A supply chain represents a "network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate customer" [8]. The discipline of Supply Chain Management aims to integrate and coordinate these normally encapsulated processes (possibly hosted by different organizations) [9]. Today's planning approaches produce optimal results if such processes are seen as encapsulated ones since inside an organization where the information coverage is pretty decent. Individual organisations usually have developed in time processes (see Figure 1), information systems and approaches to bring more flexibility to the planning approaches. Unforeseeable events like as late arrivals due to a traffic conditions or ad-hoc re-scheduling due to available freight space may be handled via manual adaption of the operational plans. Also, the pro-active update of all affected resources (e.g. drivers, staff, production machines, etc.) works very well if the organization's dimensions stay under a certain boundary.

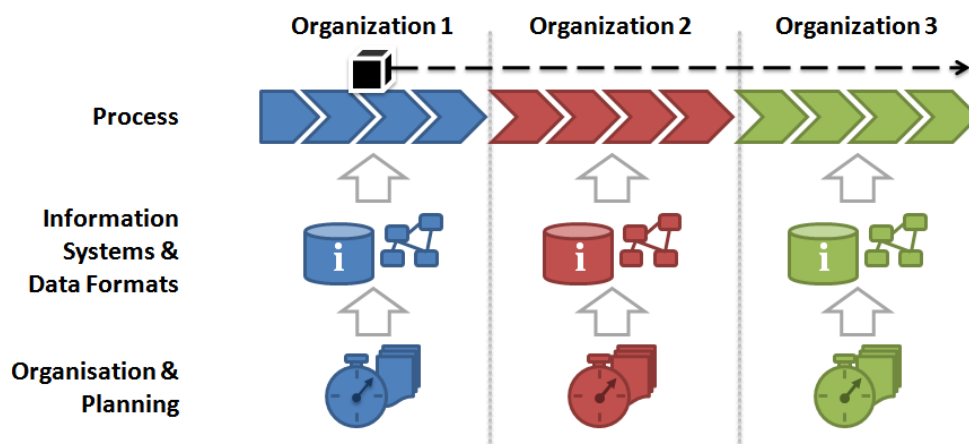


Figure 1 Planning in Supply Chain Networks

From the perspective of a whole supply chain with advanced production facilities the complexity of adapting the operational planning on unforeseeable events grows dramatically while the potential for optimisation also grows tremendously [10]. Several case studies show that information sharing across the supply chain has significant positive impact on transportation costs, warehouse fill rates or service levels [11]. The modes of information sharing they were able to observe ranges from simple exchange of production and demand forecasts via fax or email to more advanced private e-markets to have more up-to-date information for planning. While these quite basic ways of quasi-real-time synchronising the single organisations within a supply chain, still most of the optimisation opportunities remain unused. Flexible adaptations along the whole supply chain to react on failures, last minute changes or simply anomalies cannot be handled efficiently with the mechanisms highlighted.

The most convenient way of overcoming the high complexity of a problem occurring in production and supply chain lines is to divide problems into smaller sub-problems, which are less complicated and therefore more easily solvable. The overall problem is attacked by combining the single solutions of the sub-problems.

Recently, this approach was tackled with Multi Agent Systems (MAS), nowadays the technological background are advanced IoT solutions, thus solutions which origin from the idea of handling naturally distributed problems by multiple distributed problem solvers [12]. The overall problems can be divided into sub problems, which can be handled by small and manageable problem-solvers called agents or Cloud-enabled IoT devices in more modern settings and ecosystems.

## USING INDUSTRY 4.0 APPROACHES IN LOGISTICS SERVICE ECOSYSTEMS

The manufacturing challenges we are facing today need the inclusion of technological advancements in many areas. The goods transportation challenges have been described in the chapters beforehand. The manufacturing challenges are also numerous, with IoT and production machinery generating a multitude of data sets, ranging from energy measurements over production scheduling data to eco-design and sustainability of goods as well as complex equipment [13]. The common ground for the generated data sets – logistics and production – can be found in the business processes. Therefore, when combining Industry 4.0 and logistics ecosystem (a (IT) ecosystems with IT services, transportation services, booking services, and many more) it is key to combine the process view of goods with the logistics and production view. In Figure 2 an exemplary view for the product 'forklift' is shown. It is noteworthy that a forklift is a good example for the servitization aspects of Industry 4.0, meaning that rather than selling a traditional good (in this case a forklift) a producer sells the good as service (in the forklift example the producer might sell 10 000 forklift hour, with battery changes and service included). In this case, the included business processes are holistically distributed over the whole lifecycle of the forklift, from procurement of items, over production and maintenance, and lastly recycling. These processes include the traditional supply chain, logistics, or manufacturing.

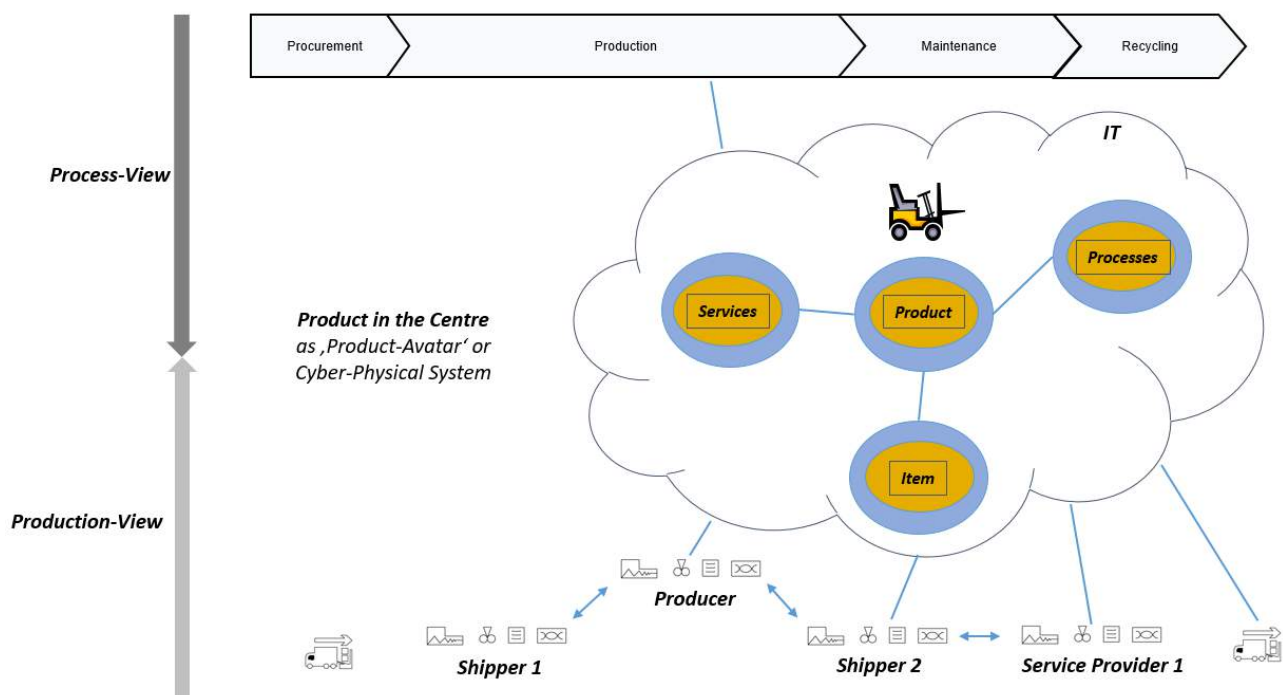


Figure 2: The product in the centre: combining process and product view

If the single components used in manufacturing are seen as 'thing' in the IoT or Internet of Everything (IoE, [4]) sense, the data from all the mentioned processes can be used in a smart way to bridge the worlds from innovative logistics service ecosystems and Industry 4.0.

Unfortunately, the detailed technical description of used protocols and listing of adequate software tools and solutions is out of scope of this paper. Nevertheless, the EU FP7 projects EURIDICE and iCargo (see also [1] and [2]) have dedicated a great deal to find a proper technical foundation. A schematic overview over their findings can be seen in Figure 3. (IoT) events are hereby forwarded from the local 'thing' level to a local intelligence (cargo events or component events in manufacturing), forwarded to the business intelligence level, where they are finally integrated in the holistic process view.

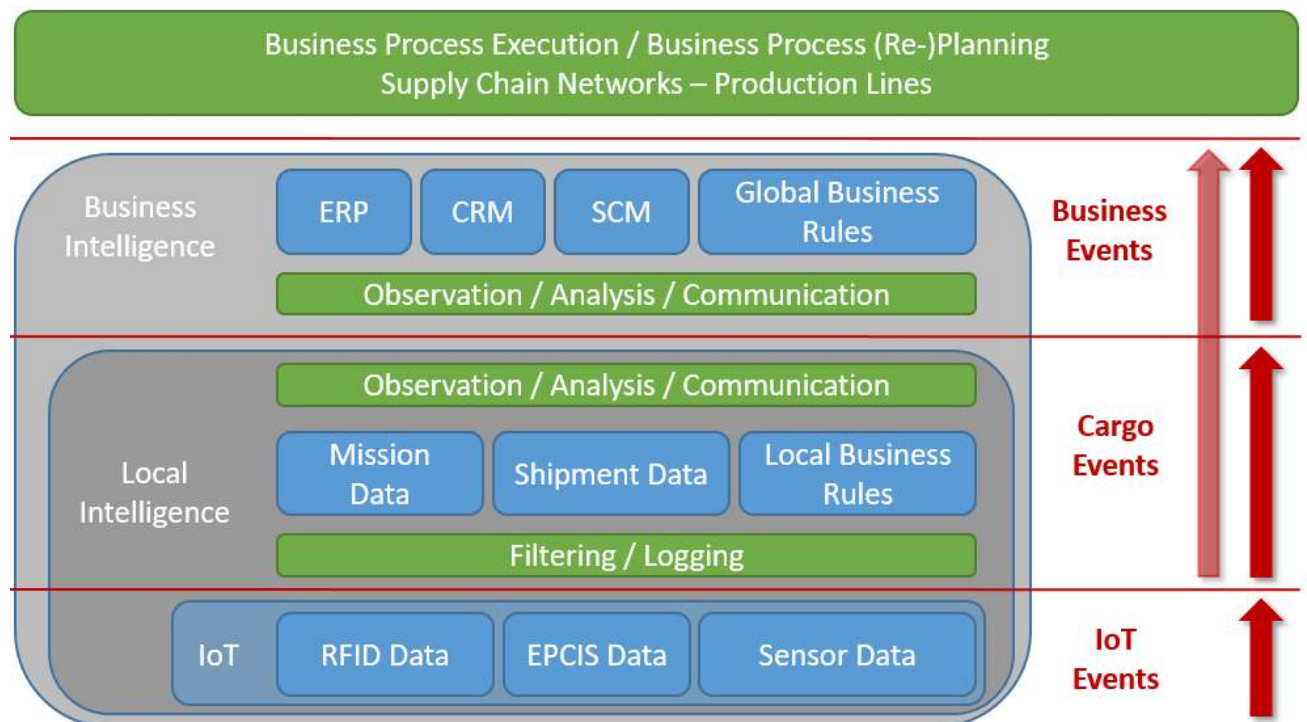


Figure 3: Event chains in modern production environments as described in the EURIDICE and iCargo projects

## SUMMARY AND OUTLOOK: APPLICATION SCENARIOS AND CHALLENGES FOR THE FUTURE COMBINATION OF LOGISTICS AND INDUSTRY 4.0

In this paper, we have described trends in supply chain management as well as production and laid out what emerging technologies are enabling these fields. In the upcoming years, the challenge for the sectors will be the combination of cyber-physical system both from the machinery of the production and the supply chain. The way to achieve this is the integration of data and local intelligence using smart local devices with decentralised decision making, whereas advanced IoT technologies are a key enabler.

The application scenarios stemming from these efforts are manifold, including, but not limited to:

- Distributed pan-European marketplaces, for transportation, manufacturing, recycling or the Circular Economy

- Collaborative planning and exception handling for logistics and manufacturing across company borders
- Distributed production line, items, and cargo surveillance; tracking and tracing as well as emission monitoring and other sustainability related optimisations
- Collaboration for the back-office across company border and a more open approach towards data sharing between trusted partners for the whole lifecycle of a product

Smart, advanced supply chain management and Industry 4.0 are interesting, but also challenging endeavours. If the research landscape can provide a solid foundation for the combination of technologies, processes, and data, a serious competitive advantage can be generated for all stakeholders.

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# **IDENTIFYING FUTURE 3D-PRINTING-RELATED SERVICES: INSIGHTS FROM DENMARK AND GERMANY**

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## **INTRODUCTION**

Many firms across a diverse range of industries are exploring 3D printing for multiple applications including prototyping, tooling and component manufacturing. Multiple 3D printing service providers have begun offering services related to the selling and servicing of additive manufacturing equipment, alongside facilitative, generative and selective services (Rogers et al., 2017), frequently coupling them with other consultancy and feasibility analysis services (Sasson and Johnson, 2016). Scholars in operations and supply chain management have now begun to research the adoption rates and implications of 3D printing across the supply chain. Holzmann et al. (2017) note that the 3D printing industry is conducive to user entrepreneurship because of its distinctive characteristics. Through the lens of diffusion of innovation (DIT), Schniederjans (2016) found that the perceived relative advantage of the technology and the resulting performance expectations serve as strong motivators to adopt 3D printing. The motivations for implementing additive manufacturing processes and the willingness to scale 3D printing production may however differ depending on the firm's stage in the adoption cycle and their current level of maturity in adoption. Nevertheless, only a limited amount of research is currently available on adoption of 3D printing services, particularly those employed by industrial manufacturing companies and the challenges faced by them in adoption.

This study seeks to address these gaps in research by providing new insights into the practices of industrial firms implementing 3D printing and the challenges they face in doing so. By identifying disparities between the needs of these firms and the types of services offered by 3D printing service providers, the study furthermore seeks to present a potential portfolio of services which 3D printing service providers can offer during the pre-installation, installation and post-installation phases of 3D printers. Such services are expected to improve the competitiveness of 3D printing service providers, and, more importantly, serve as a driving force in the adoption of additive manufacturing technologies among their industrial customers.

It is important to note at this stage that the term '3D printing services' is used throughout the paper in reference to services supporting the installation, maintenance and configuration of 3D printers in the facilities of a customer, as opposed to the 3D printing process itself being offered as a service on demand (the definition provided by Rogers, et al., 2017). This study examines services that are considered 'auxiliary' within the framework of Rogers, et al. (2016). This paper provides initial insights into the extent of 3D printing adoption and the corresponding challenges, risks and opportunities faced by 3D printing adopters (both customers and service providers) in Denmark and Germany.

## **LITERATURE REVIEW**

Customers can choose to have their designs 3D printed for them at the facilities of a 3D printing service provider, or may opt to conduct the 3D printing process themselves by purchasing or renting equipment, or by alternatively booking a time slot at a service provider's location. Customers can also employ rapid prototyping or facilitative services to take care of the entire process from the initial design to the printing of the physical object (Rogers et al., 2016). There are also opportunities for consultants along the entire 3D printing value chain (Holzmann et al., 2017). Holzmann et al. (2017) note this could be a low risk option for users of 3D printing who can leverage their industry know-how towards supplying consultancy services to customers in need of 3D printing expertise. Consultancy services could be provided for issues related to 3D design, technologies, or training. Other potential services with potentially higher numbers of customers, but higher exploitation costs as well, include the retail sale of 3D printers and the sale of 3D models through online platforms (Holzmann et al., 2017).

Rogers et al. (2017) provide a classification system for 3D printing as an on-demand service, identifying three types of service models: generative, facilitative and selective services. Generative services include all services that aim to generate a 3D model for the customer before subsequently 3D printing it. These encompass both 3D scanning and CAD construction services. In contrast, facilitative services focus on the printing process itself, tailoring their services to the needs of customers who already possess a 3D model, yet do not have access to suitable 3D printers that could conclude or carry out the manufacturing process. These can be offered both in-store and online, adhering to various business models, ranging from customer self-service at a service provider's facilities to online drag-and-drop platforms. The final category of services, selective services, does not emphasize design or manufacturing, but instead offers customers a database from which they can select a 3D model, decide how it will be printed and in some cases even customize the model itself beforehand.

A broad range of 3D printing services, particularly generative and selective services require the active involvement of the customers into the 3D printing process. Sampson and Spring (2012) outline multiple roles which service customers may adopt, including component supplier, labour, design engineer, production manager, quality assurance manager, consumer etc. In analysing online 3D printing platforms, Rayna et al. (2015) determined that the access to the means of production may eventually turn increasingly more consumers into prosumers. Varying levels of consumer involvement may provide unique opportunities for the configuration of service packages, as evidenced by the framework for consumer involvement developed by Rayna et al. (2015).



While on-demand 3D printing services have received considerable attention in recent research (Rayna et al., 2015; Rayna & Striukova, 2016; Rogers et al., 2016; Rogers, et al., 2017), little to no research has been conducted on auxiliary 3D printer-related services. These services serve as a crucial component of any feasibility study for in-house 3D printing and potentially significantly impact customers' experiences with the technology, thus leading to a long-run increase or decline in the adoption rate of the technology. This paper therefore seeks to provide preliminary insights into the rationale behind companies' attempts to implement 3D printing into their supply chains, while identifying key areas in which such services may provide additional support in order to expedite the widespread adoption and implementation of additive manufacturing.

### INTERVIEWS WITH MANUFACTURERS AND SERVICE PROVIDERS

Two separate interview questionnaires – one for 3D printing users and another for 3D printing service providers were developed based on the research gaps identified in the literature review. These questionnaires were then used to conduct semi-structured interviews with both 3D printing service providers and firms that have used such services in the past. The interview partners (see Table 1) consisted of three service providers (one in Denmark and two in Germany) and seven firms (customers) that have invested in 3D printing facilities (three in Denmark and four in Germany). The interviews were carried out from January until May 2017. These sessions were recorded, analysed and subsequently shared with the interview participants.

Category	Country	Reference	Profile
Customer of a 3D printing service provider	DK	CD1	Manufacturer for personal medical devices
	DK	CD2	Silverware business unit of a jewelry, tableware and decorative items manufacturer
	DK	CD3	Department of forensic medicine of a university
	DE	CG1	Large supplier of aerospace and automotive bearings and guidance systems
	DE	CG2	Large automotive supplier for doors, motors and seats
	DE	CG3	Leading rail infrastructure manufacturer
	DE	CG4	Medium-sized automotive supplier for plastic parts
3D printing services provider	DK	SD1	Leading service provider for plastic 3D printed items
	DE	SG1	International company with material expertise and technology know-how providing 3D printing services
	DE	SG2	Prototyping and tooling manufacturer providing 3D printing services

Table 1: Service providers (S) and customers (C) interviewed in Denmark (D) and Germany (G)

This exploratory interview approach was employed in order to identify to which extent the participating companies faced challenges in setting up 3D printing facilities, both from the perspective of firms who attempted to do so (customers)

and other firms providing support services beneficial to this endeavour (service providers).

## **FINDINGS**

The Danish users primarily applied simple to use 3D printers for prototyping and tooling, with the aim of reducing prototyping time, tooling time and overall product development time. German firms, particularly those in the automotive industry, emphasized the importance 3D printing now plays in product development and process improvement. In addition, these firms sought to develop robust process automation tools, as well as demonstrate the current and future potential for 3D printing within their organisations. CG1 and CG3 also used 3D printed versions of their products at trade fairs and sales meetings abroad, both in order to make cross-border transportation easier, and to circumvent any legal hurdles and export/import tariffs for their products.

German interviewees used additive manufacturing primarily for tooling, jig construction, prototyping and even small batch production. A number of these organisations (CG1, CG2, CG4) specified that two of the key reasons for purchasing printers were the acceleration of their learning curve for the technology, as well as the opportunity to experiment with the technology in order to assess its potential applications and determine its value for the business. The user organisations considered a faster turnaround time or order completion time and technical expertise as the most important considerations for them when choosing a 3D printing service provider, followed by the costs for the service, their ability to provide just-in-time services, as well as their quality standards and trustworthiness. All of the interviewed organisations purchased 3D printers for in-house production, rather than using the services of external service providers; however, several German interview partners specified that they had employed such services in the past for a number of years before an in-house solution became more attractive. The primary reason for purchasing 3D printers was that the services available today were found to be costly and associated with higher lead times. The customer organisations unanimously agreed that service providers need to learn to adapt to the customer's unique needs (e.g. in terms of material properties and build speed), as well as acquire more advanced printers (coupled with adequate maintenance and auxiliary services) in order to remain or become an attractive alternative to producing in-house exclusively in the long-run.

As illustrated in Table 2, all of the Danish customer cases CD1, CD2 and CD3 can be classified as having a comparatively low maturity level, but cases CD1 and CD2 can nevertheless be considered more experienced than case CD3. Case CD3 only uses desktop 3D printing machines. All Danish and German customer cases quickly experienced a need for in-house printing capacity, due to difficulties in conveying their specialized requirements to the service providers, but cases CD1 and CD2 also experienced difficulties with more advanced in-house equipment breaking down. CD2 has therefore decided to only focus on using simpler

desktop machines in-house, remaining reluctant to make the big investments that might allow the company to manufacture more complex solutions beyond tooling. CD2 could not find service providers with the equipment and infrastructure needed to produce on the more advanced level it sought. Customers CG2 and CG3 specified requiring strict norms and policies for their manufacturing processes due to the potential harm a faulty product could cause, i.e. when a train or car relies on that particular component, making it challenging to employ 3D printing processes in any end-product. Case CD3 would prefer having on-site support from their service provider, but could not request such services from their current partner. It is important to note that certain service providers do deliver such services if needed, as seen in the case of SD1, however such firms seek out customers with more advanced manufacturing requirements than CD3.

	Challenges and barriers faced by customers in adopting 3D printing	C D 1	C D 2	C D 3	C G 1	C G 2	C G 3	C G 4	S D 1	S G 1	S G 2	#
Decision to use a service provider	Difficulty in developing a business case	X	X				X		X			4
	Difficulty in understanding what can be printed, using which machinery, for which purposes						X		X		X	3
	Lack of a service provider which cater to specialized needs		X									1
	Difficulty or unwillingness to use other raw materials				X		X				X	3
Machine setup	Machine manufacturers offering little or no training or educational support	X			X							2
	Optimizing the process for specific parts				X	X	X			X		4
Post-installation applications	Difficulty or lack of knowledge in designing for additive manufacturing	X				X		X		X		4
	Poor end-product quality and machine breakdowns	X	X		X	X	X	X				6
	Difficulty in explaining requirements to service providers	X	X	X								3
	High cost of maintenance and spare components		X					X				2
	Lack of trained manpower who understands the equipment and the processes	X				X		X			X	4
	Service providers not proving services at the customers' facilities			X								1

Table 2: Challenges and barriers faced by customers in adopting 3D printing: perspectives of the service providers (S) and their customers (C)

Multiple challenges exist in the adoption of 3D printing. The customer organisations who participated in our research reported several practical

challenges: not all parts can be made to a satisfactory standard (particularly in terms of quality and accuracy), maintenance demands are extensive and demand specialist knowledge, and finishing can demand significant amounts of time in some cases. Three of the German customers (CG1, CG2, CG3) specified that money is not an issue when deciding whether to adopt 3D printing for a particular component or manufacturing process. Instead, the time needed to print objects and the quality issues resulting from the technology itself remain the biggest hurdles firms have yet been able to overcome. In addition, CG2 explained that so far, the firm has not succeeded in producing identical objects when repeating the printing process with the exact same parameters and materials. Given how repeatability and quality consistency can be considered two of the key success factors of a modern manufacturing process, it is therefore not surprising that most firms have not attempted to scale additive manufacturing capacities further. In addition, none of the organisations were able to create strong business cases, but nevertheless purchased the printers for the speed and flexibility they offered. Table 2 provides an overview of the challenges faced by the user organisations in adopting 3D printing and the challenges which the 3D printing service providers perceived that their customers were facing.

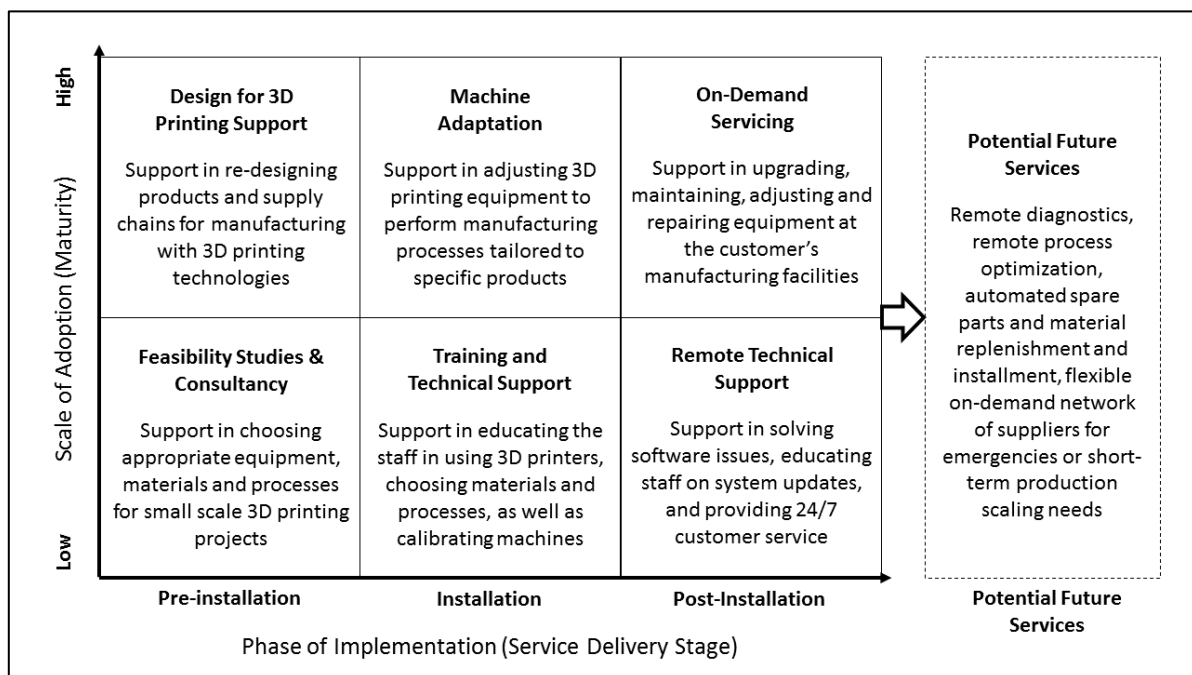


Figure 1: Maturity model for auxiliary 3D printing services

As illustrated in Figure 1, the interviews furthermore revealed that several opportunities exist for service providers to offer stronger support (and hence spur demand) throughout all adoption stages, particularly in business case development. Service providers could also seek to work more closely with their customers (Rayna et al., 2015), and provide services related to analysing which manufactured parts are most suitable for 3D printing. Service providers can also support customers in redesigning parts to make them feasible for additive

manufacturing, while helping them in choosing materials and appropriate additive manufacturing technologies. Such services would thus not only assist customers in adopting the technology, but would furthermore support them in attracting customers. At the installation phase, providing training and educational support as well as optimizing the 3D printing process for the manufacturing of specific parts are likely to be highly valued by the customers. To assist the customers in the post-installation phase, 3D printing service providers could establish a network of mobile servicing teams capable of providing on-demand 24/7 support for their installed base of printers. These teams would require trained staff who can understand customer requirements, equipment and processes clearly. In the long-run, with the integration of the 3D printer network into the Internet of Things and sensors on additive manufacturing equipment, a potential for remote diagnostics, process optimization, spare parts replenishment and automated material replacement may emerge.

## **DISCUSSION AND IMPLICATIONS**

This paper is based on an exploratory study of only seven user organisations (customers) adopting 3D printing and three 3D printing auxiliary service providers. The findings reinforce the view from existing literature that the technology and business models are still immature for large scale adoption of additive manufacturing. As Rogers et al. (2016) point out, there will be a need to understand the extent to which service providers could be integrated into the supply chains of their customers. Future research can also examine how 3D printing equipment manufacturers could develop into more involved service providers as technology advances are made. Thus, 3D printing services could provide a new research perspective on servitization. Actively involving customers in 3D printing service development and delivery could be effective as well as challenging (Westh et al., 2011) which leaves potential for further research in this domain. The findings of this study could assist 3D printing service providers in identifying and evaluating the current challenges faced by firms adopting or seeking to adopt 3D printing. This in turn may assist service providers in identifying gaps and opportunities in their service portfolio, providing an imperative for future business model and strategy development. Several delivery models may emerge, whereby individual service providers, 3D printing equipment manufacturers, consultants, industry experts and aggregator platforms dynamically adjust their service portfolio to individual customer needs. A supply chain network orchestration model for 3D printing services may also serve as a potential avenue for future research. Such a model could lead to significant cost reductions, making 3D printing more affordable to small- and medium-sized manufacturing firms as well.

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# INTERNET OF THINGS AND INDUSTRIAL SERVICE SUPPLY CHAINS

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## ABSTRACT

Internet of Things (IoT) have been recognized as one of the main trends shaping today the industrial economy. Earlier products composed solely of mechanical and electrical parts, now products have become complex systems that combine hardware, sensors, data storage, microprocessors, software, and connectivity. These "smart, connected products" are disrupting value chains, forcing companies to rethink nearly everything they do. IoT creates huge opportunities for managing product performance, utilization, and uptime, and how products work with related products in broader systems. Then the industrial service business could have completely new forms. The purpose of this paper is to analyze the meaning of IoT for the industrial service supply chains.

**KEYWORDS:** Internet of Things, Value creation, Business Models

## INTRODUCTION

Manufacturing accounts for over two thirds of EU exports and two thirds of the financing of the total private sector investment in research and development in Europe (Sanz, 2014). Manufacturing serves as a powerful engine for growth. The merging of the virtual and the physical worlds through cyber-physical systems and the resulting fusion of technical processes and business processes are leading the way to a new industrial age. This revolution has many names as Industrie 4.0, Smart factory concept, utilization of Internet of Things in industries or even Industrial Internet. This kind of initiatives has been launched in many European countries, the U.S., China, and elsewhere. Smart factory products, resources and processes are characterized by cyber-physical systems; providing significant real-time quality, time, resource, and cost advantages in comparison with classic production systems (Schwab, 2016). Despite technology industries have been the backbone of European economy, it is having today challenging times in several parts of the Europe. Digitalization has been recognized as one of the main trends shaping the industrial economy. As a meaning of the word, Digitalization is the conversion of analog information in any form such as text, images, sound or physical attributes to a digital format so that the information can be processed, stored, and transmitted through digital circuits, devices, and networks (Ng and Wakenshaw, 2017). Digitalization has potential to provide remarkably increased visibility over the technology industry processes and over the whole lifecycle of the products. Logistics and supply chain management are as well the areas for the development and improvement with the digitalization.

## DESIGN/METHODOLOGY/APPROACH

There is a common need for industrial companies utilize latest technologies for better visibility, collaboration and customer integration within the individual value chains. The aim of the paper is to discuss the effect of IoT in service supply chains. The findings in this paper are based on the review of available literature. Literature findings are enriched with the experiences from IoT implementations and service business development cases in Finland during the recent years. The importance of

service business has been understood for a while, but more systematic and integrated IoT research and development is needed in the future. The phenomenon of the IoT and digitalization is still quite a rare topic for the research in service supply chain context. By that way, the need and motivation for the studies of IoT supported service supply chains is obvious.

### **PRODUCT LIFECYCLE IN DIGITAL ERA**

Many high tech product are tailored and served to best fit for the customer specific needs. All smart, connected products, from home appliances to industrial equipment, share three core elements:

- physical components (such as mechanical and electrical parts)
- smart components (sensors, microprocessors, data storage, controls, software, an embedded operating system, and a digital user interface)
- connectivity components (ports, antennas, protocols, and networks that enable communication between the product and the product cloud, which runs on remote servers and contains the product's external operating system).

Smart, connected products require a whole new supporting technology infrastructure, which does not exist yet (Porter and Hipplemann, 2015). McFarlane and Sheffi (2003) argued 15 years ago how product lifecycles are getting shorter, resulting in lack of historical data and reducing organizations' forecasting ability. At the same time globalization trend was requiring longer and more complicated supply lines, inventory systems and distribution networks (McFarlane and Sheffi, 2003). Today globalization trend is still valid. However, additive manufacturing and usage of local resources are changing supply chain characteristics. Product lifecycles are today getting longer and longer, because of sustainability concerns. The industry sectors providing complex customer tailored product-service offerings, there are common market and product characteristics:

- Strong cyclical capital business with long-term growth potential
- Increasing flexibility in cost structures via system, subsystem and service deliveries
- System delivery cycles are long (1-2 years)
- New system/subsystem delivery includes a lot of customer specific parts.
- System lifecycles are long (up to 25 years).
- Services are important part of the business (appr. 50% of the total revenue).
- Services must be tailorable for customer specific needs.
- Tightly competed market, with long customer relationships.

Via digital channels customer can get the service faster from their solution provider or manufacturer. Increased customer satisfaction can be reached through more reliable and high quality solutions supporting the special business needs of a customer. After the delivery of customer tailored products, it is important to monitoring continuously the customer experience and retrieve the experience and usage data from products or services in order to acquire valuable information for the improvement of processes and intelligent product models. Such data provide also solid information about trends and future needs. Customer is able to get better visibility to their solution lifecycle, and better understanding of the potential value-add of the offered additional services. At the same time they can avoid unpredictable realization of risks or investments in system functionality. Substantial revenue can be generated from an installed base of products with a long life cycle. The slow economic growth during recent years has boosted the development of product-related services even more – services have brought increasing revenue for the manufacturing companies in place of traditional product sales.

One quite new view to product life-cycle management is the concept of digital twin, which was originally a 3-D virtual-reality replica of a physical product. The digital



twin allows the company to visualize the status and condition of a product that may be thousands of miles away (Porter and Hipplemann, 2015). Digital twins may also provide new insights into how products can be better designed, manufactured, operated, and serviced.

### **INTERNET OF THINGS IN SERVICE SUPPLY CHAINS**

Service supply chains are responsible typically for product deliveries, installation, maintenance, and modernization (Hemilä and Vilko, 2015). From the delivery perspective, already almost two decades Auto ID tracking of material flows has been a trend by using RFID or automated Barcode scanning methods (McFarlane and Sheffi, 2003). On those days, identification and tracking was possible in only certain points of supply chain by tracking scanners, not continuously. New IoT developments are making these scanners obsolete, as they can only collect data on broad types of items, rather than the location or condition of specific items. Newer asset tracking solutions offer much more vital and usable data, especially when paired with other IoT technologies. Physical products could be today equipped with specific technologies, so-called automatic identification and data capture (AIDC) technologies, such as radio frequency identification (RFID) tags, telematics modules or sensor tags (Papert and Pflaum, 2017). Such a products gain intelligent characteristics, including identification, localization, communication, sensing or logical functions that enable innovative IoT services for supply chain management. Today, one of the biggest IoT based trends in supply chain management is actually live and continuous asset tracking, which gives companies a way to totally overhaul their supply chain and logistics operations by giving them the tools to make better decisions and save time and money. Delivery company DHL and tech giant Cisco estimated in 2015 that IoT technologies such as asset tracking solutions could have an impact of more than \$1.9 trillion in the supply chain and logistics sector. The knowledge of an appropriate realization of IoT services is crucial for logistics companies, which traditionally are facing the limited innovation capabilities (Papert and Pflaum, 2017). Knowledge becomes even more important because IoT services represent a source for differentiation for logistics service providers.

From the product installation perspective, literature findings related to IoT utilization in installation phase are scarce. Actually, installation is manual work, without any digital aspect. However, configuring customer specific setup, testing in customer site and other software related issues could be realized by using remote control based on the IoT solution. More value from IoT could be found during the operations, within the maintenance and modernization phases. In the IoT era, products can monitor and report on their own condition and environment, helping to generate previously unavailable insights into their performance and use (Porter and Heppelmann, 2014). The manufacturer, through access to product data and the ability to anticipate, reduce, and repair failures, has an unprecedented ability to affect product performance and optimize service. The advantages for the service supply chain management are then enormous by optimizing service deliveries, maintenance and spare-part logistics. At the end, service supply chain costs can be minimized but improved value for customers.

### **NEW BUSINESS MODELS FOR INTERNET OF THINGS VALUE CHAINS**

Earlier studies have indicated that manufacturers' entire business model should be redefined for being successful and competitive in the future (Hemilä, 2016). During the recent years in different case studies, research has indicated new kind of features on business models. Business model change should be based on the strategic direction of the company. While competitive strategy approaches build on product definitions and industry structures for identifying cost or differentiation advantages, business models start with the identification of opportunities in upstream resource or downstream service markets (Ehret and Wirtz, 2017). The key aim is to identify a promising position for the company before making decisions on what unique value proposition to offer, which resources to own for capturing the

value, and what kind of partners are needed for delivering the value (Ehret and Wirtz, 2017). Value proposition in the future will be based on the Digital or Smart connected products and digital life-cycle services (Hemilä, 2016). The service supply chain partners (suppliers, logistics service providers, and other stakeholders) should be selected according their capabilities and competencies, which should directly support aims of the company. Service supply partners should provide tailored performance service offerings and right timed product-service deliveries. Service supply partners have a crucial role on the success.

The starting point of a business model is to identify market opportunities before fixing organizational structures as existing organizations may seem powerful in the exploitation of proven opportunities but show strong rigidities in exploring latent ones (Ehret and Wirtz, 2017). Porter and Heppelmann (2015) argue that new Customer Success Management (CSM) unit will define analytics based customer segments locally and globally. CSM unit continuously update movements and action in customer interface, so that company can react immediately on customer needs when needed. CSM unit should closely and continuously collaborate with service supply partners. Delivery chains will be visible and agile as digitalization enhance operations. For the logistics and supply chain the agile demand-driven supply chain partners are needed, in this study more relevant term is service supply partners. In the revenue side of business model, new performance and value based revenue models will be formed. The value capturing mechanism aims to translate value-in-use into financial value for the service provider (Ehret and Wirtz, 2017). One key motivation of IoT is to broaden potential revenue streams beyond the sales of manufacturing equipment, where in particular, business models consider contracts that include leasing, renting, maintenance and repair, predictive modelling, process optimization, licensing, and multi-sided markets where one market stimulates the cash flow of another side of the market (Ehret and Wirtz, 2017). Ng (2014) suggests that an organizational field of a value constellation in this manner could be a way to understand the institutionalized spaces of consumption and markets and how they map onto business models, i.e. that of the offering (value proposition), the experience (value creation), and the payment model or resource benefit (capture). Ng and Wakenshaw (2017) have argued if marketing is serious about its role in meeting needs and profitably in the era of IoT, it needs to rethink traditional processes of product design and innovation, and marketing's role within it. Marketing would need to bring situational and contextual insights to bear on product parameters to innovate on future offerings, and on the understanding of how consumer latent needs can emerge new generative offerings. The business model and IoT utilization challenges have been identified to include:

- Lack of adequate skill-sets to expedite the march towards fourth industrial revolution (service supply partners, as well the manufacturers themselves)
- Threat of redundancy of the corporate IT department
- General reluctance to change by stakeholders

The change is always a challenge, and digitalization is not different in that sense. New competencies are needed and organizations should learn new things and at the same time the entire ICT infrastructure should be updated.

## **CONCLUSIONS**

The contribution brings new insights to IoT phenomena in the service supply chains context. Paper narrows the gap between technologies, business and service supply chains research, by increasing the understanding of the relation between IoT and service supply chains. Paper analyses the advantages that can be realized with the utilization of IoT, and which kind of new business models for capturing value this development opens. In the future of service systems, platform thinking could also be employed in understanding IoT offerings, as the platform thinking enables the design of IoT offerings to achieve scalability through standardization of the core components that exhibit low variety, as well as personalization of the offering by

providing the peripheral components with high variety (Ng and Wakenshaw, 2017). Service supply chain design builds on the maxim that a firm is rarely in the position to exploit an opportunity on its own, thus requiring an ecosystem of service suppliers, and stakeholders to effectively serve its customers (Ehret and Wirtz, 2017). Networking is key to the configuration of IoT, as it resides on the co-creation of a wide range of players.

### **Research limitations/implications**

This paper attempt to create understanding in IoT effect on service supply chains. More practical evidence of IoT implementations are needed, which is the next step of the research. However, key infrastructures that will affect the scale and performance of IoT systems are still in an emergent state (Ehret and Wirtz, 2017). Connecting a growing range of things and machines to the Internet is at the heart of current infrastructure innovations, like the fifth generation standard for mobile communication (5G) or the development of a new IPV6 protocol for sufficient identification of the growing number of items connected to the Internet (Ehret and Wirtz, 2017).

### **Practical implications**

This paper provides for practitioners better understanding of the opportunities related to IoT in service supply chains. Practitioners should define a new kind of value capturing mechanisms for the future service supply chains, according the findings of this paper.

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# ASSESSMENT OF SERVICE QUALITY IN SUPPLY OF PHARMACEUTICAL PRODUCTS

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## ABSTRACT

Supply chain management and procurement policies can strongly influence the quality of service provided by companies, therefore its ability to compete in the market. Ten years after deregulation of the pharmaceutical market in Portugal, the industry faces strong challenges. Organized purchasing groups emerged to gain bargaining power towards suppliers. Nonetheless there are traditional players (pharmacies) who remain independent. The purpose of this paper is to assess and compare the perceived quality of the service provided by the traditional distributors with the one from the economic groups, and identify which factors need to be more developed by these groups to improve its service. Twenty pharmacies were interviewed (ten belonging to a specific economic group and ten independent ones). Findings show that the main criteria for supplier selection are the commercial conditions. Although the access to more favourable purchasing prices is the leading reason for pharmacies joining the economic group, lack of fulfilment of the overall commercial advantages announced by the economic groups (such as service consistency and price, when compared to the monthly fee payed to the group) lead some pharmacies to remain independent. Pharmacies manager's management skills were identified as an influencing factor when choosing to be part of the economic group.

Keywords: supply chain management; B2B; service quality; pharmaceutical industry; multiple case study comparison

## INTRODUCTION

Portuguese pharmacies are facing a significant increase in competition as the market is no longer as regulated as before. Ten years ago the market became deregulated and many new players (drugstores) entered the market making available all products the traditional pharmacies offered under protection rules. Only the prescribed products remain regulated and available only at the traditional pharmacies.

The drugstores complemented their value proposal by adding complimentary services, such as beauty and nutrition services, among others, representing strong competition to the well-established pharmaceutical market. These new players pressured selling prices down and margins no longer support low rotation inventories or urgent deliveries (that sometimes were available up to 5 times a day) at small volume pharmacies.

One way the pharmaceutical industry found to fight this competitive battle and gain bargaining power towards its suppliers was to aggregate pharmacies in economic groups. These groups allow purchasing products at lower prices due to more bargaining power and aim for high quality in service delivery. At the same time some of these groups also provide management support for those who end up managing the pharmacies but have no management background.

The span of services available at the pharmacies is an important issue for the customers, as well as product availability and attentive care (Silva, 2015). These are some of the issues that influence end customers when deciding where to purchase. By

providing a service that matches retailer's expectations, suppliers can contribute to their development of competitive advantage (Mentzer et al., 2008).

Every pharmaceutical product is potentially available at any pharmacy so besides complimentary services what leads a customer to a specific pharmacy instead of another? Customer service is a strong driver and product availability is at its centre. At the same time investment in inventory is a major concern for the pharmacies as variety is wide and demand uncertainty high. Assuring immediate product availability is a major challenge for pharmacies and overcoming the lead-time gap (Christopher, 2016) is a permanent management issue. Purchasing costs are a major concern as well as on time deliveries, which are issues that pharmacies consider when deciding to join these economic groups or to keep purchasing from the traditional distributors. Under this context, the purpose of this paper is to perceive if there are differences in terms of the supply services provided by the economic groups to its joining pharmacies and the one provided by the traditional distributors/wholesalers, and identify if there are factors that these groups need to improve to make a better service available to the pharmacies. Therefore this research has two main objectives. The first one is to assess and compare the perceived quality of the service provided by the traditional supply chain agreements and the one made available by the economic groups. The second is to identify specific ways in which the economic groups can improve their service. Assessment will be based on the perspective of the customers of the economic groups, i.e., the pharmacies compared to perception of service received by pharmacies that maintain the traditional supply system.

In order to achieve its goal this research grounds its literature review on supply chain management and service quality. Two groups of 10 pharmacies each are compared, one belonging to a specific economic group e the other constituted out of independent pharmacies. Interviews were conducted with the managers of these pharmacies. Content analysis was used for the treatment and analysis of interviews.

## **LITERATURE REVIEW**

It is customer service that more and more sets the difference between the offerings from different players in the same industry (Christopher, 2016). Product availability is one of the most relevant issues in customer service as, although slowly, markets are becoming less sensitive to product brand. This can easily lead to lost sales for the supplier but not exactly to the point of sales as substitute products might be available. Mentzer et al. (2008) posit that by supplying good logistics service companies can add value to the value proposition for the customer and therefore support its customer to sustain competitive advantage in their own market. According to the same authors, this competitive advantage can be achieved with product availability, on time delivery and error free orders. Being able to compete in the market is therefore a consequence of the level of customer value provided, which is heavily influenced by the suppliers' service quality.

Supplier selection if a source of competitive advantage as the player is only as strong as the supply chain it is part of. Strategic procurement can set the competitive scenario of a company when compared with others in the same industry (Simchi-Levi et al., 2008). Searching for the best supply is a dynamic process that impacts the quality of the service the companies provide to their own customers. Being able to develop bargaining power and reduce supplier dependency is a way to reduce procurement costs (Kraljic, 1983).

Procurement plays a major role in creating supply chain resilience (Pereira et al., 2014). In markets where product availability plays a key role in customer service, being able to assure the best suppliers is of paramount relevance. In parallel, being able to supply competitive and resilient service influence buyers to consider those suppliers during their sourcing exercises. Service consistency and short lead times are relevant procurement issues as the retail customer, specifically in the pharmacy's market, aims a very short order cycle (Christopher, 2016).

Based on the conceptual framework, the research question pursued in this research is:

- *In the retail pharmaceutical market, which issues are enhancing or preventing the retailers from joining economic groups and what are the issues these groups should focus on to enhance their service quality to become more attractive for pharmacies' sourcing strategies?*

## **METHODOLOGY AND METHOD**

Research focusses com a single economic group. Pharmacies that are part of this group are compared with a group of similar dimension of independent pharmacies.

The data collecting tool was interview. There were two frames for the interviews, one for the pharmacies that belong to the economic group and one for the pharmacies that do not. The structure of the interview used for the pharmacies that are independent is composed out of three parts: the first one focussed on the pharmacy, its supply and the satisfaction level with the service provided by the suppliers; the second part aimed at topics concerning the reasons that lead the pharmacy not to join any economic group; lastly, a set of topics concerning the quality of the logistic service provided by the pharmacy to its customers. The structure used for the pharmacies that belong to the economic group was also composed out of three parts: the first one focusses on the reasons for joining the economic group; the second part aimed at the satisfaction level with the logistic service and support received from the economic group; the last part aimed at the logistic service provided by the wholesalers the economic group has agreements with its own customers (the joining pharmacies). Wording was adjusted during the interviews to assure interviewee understanding of the topics.

Twenty pharmacies were selected for this research. Out of the 20 selected pharmacies, 10 are part of the economic group and 10 are independent. In order to add variability of context to the research, pharmacies were selected from different districts of Portugal: 12 from Lisbon, 2 from Setúbal, 2 from Évora and 4 from Portalegre.

Interviews were performed with the owner of the pharmacy (which in some cases is also the technical director). Each interview lasted for about 15 to 30 minutes. There were 18 face to face interviews and two interviews performed over the phone.

Interviews were written down and then key words (or its synonymous) were searched for. Data analysis followed Krippendorff (2013)'s recommendation for content analysis.

## **STRUCTURE OF SUPPLY OF PHARMACEUTICAL PRODUCTS**

Portuguese pharmacies can purchase directly from the laboratories or through wholesalers. The laboratories are the producers of the medicines or of other products. The wholesalers purchase from different producers/brands and then supply the pharmacies with a wider range of products.

Globally, all pharmacies have (more or less formal) agreements with the wholesalers from which they receive products on a daily basis. If the wholesaler does not have the product available or in order to use eventual commercial campaigns the pharmacy can purchase directly from the lab. Nonetheless, some pharmacies chose to purchase only from the wholesalers.

The wholesalers' service level depends on the commercial conditions agreed with the pharmacy (service, volume, selling price, number of daily deliveries). Lead times are usually short, of 12 hours up to one day.

The Portuguese pharmaceutical market is strongly regulated and selling prices for medicines are defined by a public institute. These prices are considered low for the labs and wholesalers. These wholesalers can also distribute products to other markets, less regulated or with higher selling prices and it is not unusual that stock outs occur in the Portuguese market because the products were send to more profitable markets. Pharmacies that are part of the researched economic group have access to a purchasing office for all purchases and services. For confidentiality reasons this group is not identified, and will from this point forward be called Group X. Using this Group X the pharmacies have access to lower purchasing prices, which were previously negotiated between the group and the supplier (lab or other supplier). The purchasing price is always an advantage but the service level depends on commercial conditions

negotiated by Group X with the wholesaler. Group X developed commercial agreements with three wholesalers. These wholesalers are not exclusive to Group X. Pharmacies who purchase under the scope of Group X order directly from these wholesalers.

Being born in 2008, by the beginning of May 2017 Group X represented 401 pharmacies. Besides a purchasing centre, Group X provides marketing, financial and human resources management support to their associates, as well as training and in store organization. There are also available specific shared services (such as nutrition) that otherwise the pharmacies would not have enough volume to support. Once part of Group X the pharmacies receive a total makeover of the facilities to assure similar commercial image at all pharmacies in the group. In exchange to the package of services pharmacies pay a monthly fee plus a per cent over their sales.

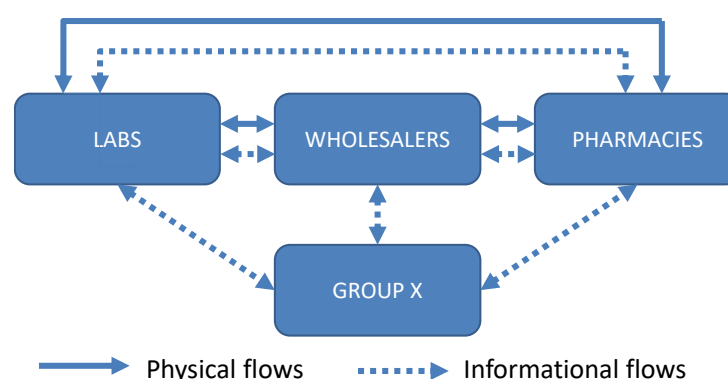


Figure 1 – Physical and informational flows in the supply chain of Group X

Figure 1 shows the physical and the informational flows between the pharmacies that belong to Group X and the players in the supply chain.

There is always a direct and an inverse flow between every entity as returns can occur (due to expiry dates or service issues). Group X works as a purchasing office and does not hold inventory. It also works as an advisory player for management purposes and planner of additional services. The independent pharmacies (that do not belong to Group X) are linked both to the wholesales and the labs as they are not limited to purchase from the wholesalers.

## FINDINGS

When analysing the criteria used by the pharmacies to select their suppliers, findings showed that it is mostly based on commercial conditions offered and product availability. Table 1 shows the main results.

Table 1 – Criteria considered when selecting suppliers

Criteria	Relative per cent (1)
Payment conditions and lead time	100%
Product price	50% (2)
Product availability	50%
Delivery time range and availability during weekends	20%

(1) Out of the 20 interviewed pharmacies

(2) All the pharmacies belonging to Group X (100%)

All the pharmacies belonging to Group X mentioned that they prefer to use the wholesalers with which Group X has agreement. Nonetheless, only 20% of them purchase exclusively from such wholesalers (these pharmacies are owned directly by Group X), when 80% of them state that they preferentially buy from these wholesalers but keep contacts with other wholesalers or labs to complement their offer, to assure supply (not always the wholesalers that have agreements with Group X have product



availability either because Group X missed placing the order or the product is out of stock). Taking advantage of specific campaigns was a criteria mentioned by all the pharmacies that are not part of Group X to purchase specifically from the labs.

In terms of satisfaction with the service provided by their suppliers, Table 2 shows the distribution of answers on a scale from 1 to 1. None of the sampled pharmacies is completely satisfied with the service received from its suppliers but at the same time there are no observations bellow the middle point of the scale, which allows concluding that there are no situations of dissatisfaction. The median satisfaction level is 5, which allows concluding there is room for improvement in terms of the service provided by the pharmacies.

Table 2 – Satisfaction with suppliers' service

Value of scale	1	2	3	4	5	6	7
Per cent	0%	0%	0%	20%	45%	35%	0%

(Legend: 1 – Not satisfied at all; 7 – Completely satisfied)

Table 3 allows comparing the satisfaction of the pharmacies supplied under the scope of Group X and the independent ones. Although the satisfaction level is similar in both groups, there is stronger agreement between the independent pharmacies. Pharmacies supplied under the scope of Group X complain mainly of the lack of ability of the wholesalers to deal with such high level of demand and the stock outs. The wider variability of responses from Group X's pharmacies can also be justified due to the fact that two of these are actually owned by the Group, situation that might prevent those two managers from exposing the real satisfaction level with the wholesalers.

Table 3 – Comparison of satisfaction between groups of pharmacies (supply)

	Global satisfaction	Pharmacies supplied under the scope of Group X	Independent pharmacies
Median	5	5	5
Interquartile interval	1	2	1

Both groups mention lack of product availability as the main reason for their lack of satisfaction. Smaller pharmacies are additionally concerned about this issue as when products are rationed they are usually penalized receiving even less quantity. As for the wholesalers suppling at the prices negotiated by Group X, it is often that they channel their product availability to more profitable customers than to Group X's. Nonetheless, when comparing the two distributions the Mann-Whitney test revealed that the difference is not statistically relevant ( $p=0,392$ ).

Pharmacies in Group X were asked about the reasons for joining the Group. As 2 of them are owned by the Group, only 8 pharmacies were questioned about this topic. Table 4 shows the relative frequency of answers. Pharmacies could identify more than one reason for joining the Group.

Table 4 – Reasons for joining Group X

Reasons for joining	Relative per cent
Access to more favourable prices	63%
Offer of specialized services	50%
Recognition of Group X as having a new strategic model	38%
Need to adapt to the new legal conditions	25%
Differentiation of final service	13%
Improved competences to serve customers	13%

Although financial issues are the main reason for joining Group X, pharmacies also pointed the additional services made available by Group X as a selling issue. Nonetheless, although more affordable prices is the key issue, it has been identified as a selling point Group X cannot fulfil. In fact, this is only a theoretical advantage as it was recognised by these pharmacies that product availability is poor at the selected wholesalers. This is also a reason for these pharmacies to maintain agreements with other wholesalers beyond the selected three.

As for the currently independent pharmacies, Table 5 shows the reasons stated for not joining any economic group.

Table 5 – Reasons for not joining any economic group

Reasons for not joining	Relative per cent
It has not yet been considered	30%
Commercial advantages presented do not compensate	30%
Want to keep their independence	20%
No group has yet showed enough advantages	20%

Findings show that the financial advantages were not enough to capture the attention of these pharmacies. The more modern looking ones do not recognise the need for the support of one of these groups, which leads to conclude that the physical support at the point of sales could be also considered a good value proposition from Group X.

In most cases the technical director of the pharmacy is also the owner, which means that that person has to divide its attention between the technical support to the customers and the management of the business. In one specific case the technical director is fully dedicated to the management of the business and stated that he can achieve as good financial deals as the ones offered by the groups, but that it only happens as a consequence of his time investment in procurement.

When questioned about the quality of the services offered to its own customers, findings showed that the pharmacies recognise that there is scope for improvement. Table 6 shows the results obtained. Although no pharmacy scored below the middle point of the scale, only 10% are fully satisfied with the service provided and the median is at 5 out of a scale of 7 points.

When results from the satisfaction with the service provided (Table 6) are compared with the satisfaction level with the suppliers (Table 2), it can be stated that pharmacies are more pleased with their own service than with the service received from its suppliers.

Table 6 - Satisfaction with its own customer service

Value of scale	1	2	3	4	5	6	7
Per cent	0%	0%	0%	0%	55%	35%	10%

(Legend: 1 – Not satisfied at all; 7 – Completely satisfied)

Comparing the two groups of pharmacies (independent ones vs belonging to Group X), although the satisfaction level with the service provided is higher at pharmacies belonging to Group X than at independent pharmacies, the spread of responses is also higher (Table 7). As 20% of the pharmacies from Group X are owned by the Group, it is possible that is might be influencing the responses.

Table 7 – Comparison of satisfaction between groups of pharmacies (service provided)

	Global satisfaction	Pharmacies belonging to Group X	Independent pharmacies
Median	5	6	5
Interquartile interval	1	1	0

## **DISCUSSION**

Group X assortment is limited, which leads some pharmacies to keep supply agreements with additional suppliers to complement the range of their offer. These parallel agreements also allow taking advantage from campaigns offered by other wholesales or even the labs.

Although lead time was a criterion identified by all pharmacies as a very relevant one to be part of the Group, 8 out of the 10 pharmacies that belong to Group X keep agreements with other suppliers and product availability is one of the reasons. This leads to conclude that although Group X announces a specific lead time, the wholesalers they have agreements with do not fulfil it. The price of the products and product availability were reasons identified by all the pharmacies belonging to Group X for joining the Group. As product availability is not assured at the agreed price, it is possible to conclude that the Group is not providing the main advantages recognised by the pharmacies, forcing these to keep agreements with other wholesalers and endangering the willingness of the pharmacies to keep being part of the Group.

Although the access to more favourable purchasing prices is the leading reason for pharmacies joining Group X, fulfilment of commercial advantages is not recognised latter on (such as service consistency and price, when compared to the monthly fee paid to the group) and lead some pharmacies to keep managing purchasing relations by themselves (being independent from any group).

Pharmacies belonging to Group X show a higher satisfaction level with the quality of the service they provide. In fact, one of the main alterations a pharmacy received when joining the group is the complete alteration of the physical appearance of the space (more modern), customer service training is provided to the store's employees and complimentary services become available for their customers, which influences the satisfaction level they have with the quality of the service they provide. Nonetheless, product availability is a major concern for pharmacies belonging to Group X, which can reduce their satisfaction level with the service provided.

Based on the results obtained, even considering that the sample is not representative of the industry, it is possible to posit that Group X is experiencing some problems in fulfilling the promises it makes to the pharmacies of the Group, especially in terms of product availability at the more favourable prices. Nonetheless, widening the services made available at the pharmacies and the new visual appearance of the spaces are topics well perceived by the pharmacies. As the commercial conditions are a key issue for joining Group X, the Group should adjust its procurement strategies to meet the expectations of its customers (either by developing more bargaining power towards wholesalers to assure supply, or run its own distribution centre to be able to fulfil orders from the pharmacies that join in – both in terms of volume and in terms of lead time fulfilment).

## **CONCLUSIONS**

This research aimed at assessing and comparing the quality of the service provided by the traditional distribution system of pharmaceutical products in Portugal and the one made available by the economic groups that emerged when the industry became less regulated. The assessment was put to practice from the perspective of the pharmacies.

Findings lead to conclude that when managers of pharmacies have more time to dedicate to procurement issues it is possible to achieve better quality of supply (price, lead time consistency and product availability) than the service provided by the wholesales with agreements with the economic group analysed. These issues are the more relevant ones for the pharmacies when assessing their suppliers but the pharmacies of the analysed group need to keep parallel suppliers to achieve the service supply their desire. Product availability issues should be the main focus of the group if it wants to improve the quality of the service provided. Nonetheless the Group is well recognised for the range of complementary services made available for its pharmacies and the marketing support they provide.

A single economic group as analysed and the sample used was limited (only 20 pharmacies). It would be interesting to expand this research to more pharmacies of the same group. In the same line of research, it would be interesting to compare the difficulties of supply of this Group with other economic groups. As the quality of the service provided is better assessed by its customers, further research should be performed to assess if the quality of supply influences customers' perceived quality of the service provided at the pharmacies.

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# **AN E-COMMERCE ORDER HANDLING SYSTEM FOR E-LOGISTICS PROCESS RE-ENGINEERING**

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## **Abstract**

### **Purpose of this paper:**

The emerging and ever expanding e-commerce business has created huge market opportunities for logistics service providers (LSPs) to grasp. However, LSPs who target at e-commerce business are required to strengthen their internal order processing capability through logistics process re-engineering. Such transformation is never a simple task to execute without IT enabling. In view of the emerging challenges and needs, this paper develops a GA-case-based decision support module, which integrates the concept of "Warehouse postponement" to re-design the process flow of e-commerce logistics order operations in distribution centres. The proposed system serves as a disruptive technology to re-engineer logistics order processing for e-commerce orders, thereby removing any potential bottleneck along a supply chain due to the operating inefficiency for e-commerce businesses.

### **Design/methodology/approach:**

With the vast differences of the order nature and handling requirements between conventional logistics orders and e-commerce orders, this paper sheds light on and integrates the concept of "Warehouse postponement", by developing a hybrid decision support system that incorporates genetic algorithm (GA) and case-based reasoning (CBR) for, respectively, discrete order consolidation, followed by order re-grouping for ease of order picking operations performed in distribution centres. In this sense, LSPs are able to transform their business into an e-commerce-oriented one with significant improvement of e-commerce order handling efficiency in distribution centres.

### **Findings:**

The proposed system is validated through a pilot study in a case company which is capturing e-commerce logistics business. Upon successful pilot implementation, a significant internal order handling efficiency improvement, measured by the average throughput rate per e-commerce order and the average traveling distance of each e-commerce order, is found.

### **Value:**

This study fills the gap in the literature by providing a light-weight decision support system that integrates artificial intelligence techniques to tackle industrial operational problems specifically under e-commerce logistics operating environment. We contribute to the wider body of scientific knowledge that has not studied the need of logistics re-engineering in supply chain management under today's emerging e-commerce market.

## **INTRODUCTION**

E-commerce order fulfilment is one of the biggest challenges not only among logistics practitioners, but also the e-retailers who sell their products via the internet. In the past decade, with the advances and rapid development of cloud computing technologies and mobile networks, business-to-customer (B2C) transactions no longer take place solely at physical stores. End consumers are able to purchase goods simply by browsing the internet with the use of their smartphones and tablet computers. They do not even have to stay in front of a desktop computer to confirm and make a purchase, making shopping more convenient than anyone expected before. However, problems arise behind the scenes of online shopping. While we are able to purchase items anytime and anywhere, it is up to the logistics service providers (LSPs) to handle the entire order fulfilment processes in a

time-sensitive and accurate manner. Without geographical limitations of placing an order, upon fulfilling the order in a warehouse or distribution centre, local LSPs transport the consolidated goods to freight forwarders to handle the transshipment part of the order. Couriers are also involved at the end of the supply chain for the final, direct last-mile delivery of purchased goods to the end customers. Each party along the supply chain of the e-commerce business relies on the preceding party. In this sense, any operating inefficiency of a single party along the supply chain could easily lead to a bottleneck in the order fulfilment, which would seriously affect the overall e-order fulfilment efficiency of the entire supply chain.

The emerging and ever expanding e-commerce business has created a huge market segment for LSPs to compete in. It is, however, never easy for them to grasp the opportunities and gain a portion of the market pie without re-designing and re-engineering the logistics operating flow. In contrast to traditional logistics orders handled in warehouses, which are mostly handled in bulk with an identical SKU for each order for regular stock replenishment to physical retail stores, the e-orders handled by LSPs in the world of e-commerce are in small lot-sizes but with a large number of SKUs involved in each order (Leung et al., 2016). The large number of discrete e-orders arrive irregularly and unpredictably, plus the requirement of next-day or even same-day delivery upon receiving the order has also added to the complexity in handling.

With such a large gap between traditional order fulfilment and today's emerging e-commerce order fulfilment, logistics practitioners cannot survive without proper IT as a support in decision-making, not to mention the challenges they have been facing, such as global economic instability, increasing customer requirements, fluctuating customer demand, increasing complexity of order handling, and difficulty in hiring warehouse operators. It is not difficult to comprehend that, in the absence of any IT aiding decision support under today's complex e-commerce order fulfilment process, LSPs would face severe consequences in their e-commerce logistics business, such as:

- Unsatisfactory performance in handling e-commerce orders in distribution centres
- Overall supply chain inefficiency due to a long lead time of order processing along the supply chain
- Customer dissatisfaction due to delayed response time and last-mile delivery
- Reputation loss of both e-retailers and LSPs

In view of the necessity of LSPs to re-engineer the entire logistics process so that it complies with the order handling requirements of e-commerce business, this study proposes a hybrid decision support system which embeds the concept of "Warehouse postponement" for e-commerce business. This is achieved by incorporating genetic algorithm (GA) and case-based reasoning (CBR) technique as the tools to provide managers with decision support for streamlining the e-commerce order processing in warehouses and distribution centres. This paper contributes to the wider body of scientific knowledge that has not yet been studied on the need of logistics re-engineering in the logistics and transportation sector under today's emerging e-commerce market. This study fills the gap in the literature by providing a light-weight decision support tool that integrates artificial intelligence techniques to tackle industrial operational problems in the e-commerce logistics operating environment, with the intention of disrupting the traditional way of handling e-commerce orders.

## **LITERATURE REVIEW**

### **Warehouse order-picking operations under the era of e-commerce**

Warehouses and distribution centres play a vital role in supply chains but various challenges are found throughout the operational flow (Andriansyah, 2013). Among the typical warehouse operating categories, including receiving, put-away, storage and delivery (Berg and Zijm, 1999), several studies have revealed that order picking, a process of retrieving items from storage locations in warehouses or distribution centres to fulfil customer orders, is one of the most time-consuming and cost-intensive warehousing

activities (Roodbergen and de Koster, 2001; de Koster, Le-Duc and Roodbergen, 2007; Rushton, Croucher and Baker, 2014;). Hence, order picking is perceived by logistics practitioners as a critical warehousing activity that has a direct impact on service levels, customer satisfaction and delivery timeliness (Battini et al., 2015), and has the highest priority in productivity management (de Koster, Le-Duc, & Roodbergen, 2007). Numerous studies highlighted the importance of warehouse operational efficiency improvement, and proposed heuristics and optimization methods for order picking. De Koster, Le-Duc, and Roodbergen (2007) provided a comprehensive review of order-picking systems. However, even though warehousing processes can be automated and previous literature suggested various means of improving warehouse operation efficiency, most LSPs, particularly small and medium-sized, are still manually performing operations in warehouses, with a lack of IT support (Richards, 2014).

In the era of e-commerce, the change of order profiles resulted in a smaller lot sizes in a single delivery request, with a tighter delivery schedule. Same-day deliveries have gradually become a fundamental element of e-commerce businesses (Yaman, Karasan, & Kara, 2012). The pressure is on the side of LSPs who in demand for efficiently handling customer orders, timely and accurately. With the dynamic arrival of discrete, small lot-sized e-orders from customers, an order batching strategy is perceived as a useful operating strategy to reduce the number of picking trips, thereby saving time, distance and operating costs by aggregating orders (de Koster, Le-Duc and Roodbergen, 2007; Ruben and Jacobs, 1999). In the mainstream literature, many heuristic algorithms have been proposed to tackle the problem of order batching. For manual order picking systems, savings and seed algorithms are the most commonly used methods (e.g. Clarke and Wright, 1964; Ho and Tseng, 2006). Due to the difficulty and impracticality in obtaining an exact solution, a heuristic approach is proposed in order for the concept of warehouse postponement to be realized. GA and CBR is selected for integration into the proposed decision support system.

### **AI techniques for logistics operational decision support**

First introduced by Holland (1975), the genetic algorithm (GA) was conceptualized to solve industrial optimization problems by encoding the potential solutions as a string composed of several components, defining the fitness function, and then recombining and mutating their components. Until the stopping criteria is satisfied, an optimized solution is obtained and iterations end, stopping the chromosomes from further evolving. According to Goldberg (1989), the GA is a robust AI technique that can be applied into complex environments due to its reliability and flexibility in solving combinatorial and multimodal problems. In previous studies, researchers extensively applied GA into various areas related to warehousing operations. Hsu et al. (2005) applied Genetic Algorithms to deal with order batching problems that minimized the total distance travelled. Tsai et al. (2008) proposed a multiple-GA method for obtaining the best possible batch picking plans, with consideration of earliness and tardiness penalties on orders. Lam et al. (2013, 2015) integrated GA with CBR for risk management and mitigation in warehouses.

Case-based reasoning is a knowledge repository and learning tool that is fundamentally different from other artificial intelligent techniques (Aamodt and Plaza, 1994). By capturing prior experience and turning it into explicit knowledge (Craw et al., 2006), a CBR engine compares the similarity of the current scenario with previous situations organized as "cases", to provide decision support for the current problem. CBR has been extensively applied in the logistics operating environment for decision support, such as in warehouse resource management (Chow et al., 2006) and risk mitigation in warehouses (Lam et al., 2013, 2015).

In an effort to improve the warehouse operational efficiency under a dynamic e-commerce operating environment, in which customer orders arrive at more irregular time intervals and with much higher frequency, we propose a hybrid GA-case-based decision support system, integrating GA and CBR, for specifically tackling fragmented e-commerce

customer orders. The proposed method goes beyond the traditional concept of order batching. Instead of solely aggregating orders until reaching a specified capacity constraint threshold, the proposed solution applies the concept of "Warehouse Postponement", which is defined as the postponement of warehouse operations until the last possible moment (Leung et al., 2016). The fundamental difference between Warehouse Postponement and order batching is that order batching is a general method of grouping a set of orders into several sub sets, which is oriented by the received orders; whereas Warehouse Postponement is a process-oriented operational strategy that has a wider concept of not only grouping, rearranging or re-categorizing outstanding orders based on their similarities for further batch or wave processing, but also flexibly taking into considerations of "when to batch", "what to batch", and "how to batch". Such concept best suits environments like in e-commerce logistics businesses due to their dynamicity and complexity.

### **ARCHITECTURE OF E-COMMERCE ORDER POSTPONEMENT SYSTEM**

A decision support system that integrates the concept of Warehouse Postponement, namely E-commerce Order Postponement System (EOPS), is presented in this section. EOPS incorporates the genetic algorithm for initiating an order picking wave, and case-based reasoning for generating the sequence of picking items in the storage locations, thereby providing logistics practitioners with decision support to practically apply Warehouse Postponement into a real production environment. Figure 1 shows the architecture of EOPS. With the proposed hybrid decision support system, the logistics flow of operations in warehouses or distribution centres after order delivery requests from e-retailers is redefined. Orders are no longer processed immediately, but consolidated into a so-called "Order consolidation pool". Until the last possible moment, consolidated orders will not be processed in the warehouse. Upon placing an order via any point of sales the e-retailers make available, the e-retailers, who outsource the entire warehousing, stock-keeping and shipping functions to a designated LSP, submit delivery requests to the LSP to process the orders, timely and accordingly. EOPS consolidates the outstanding customer delivery orders requested by e-retailers and then logically splits these customer orders into several order picking lists with the use of GA, so as to allow warehouse order pickers to execute order picking operations simply according to the list. To further streamline the actual picking operations, a suggested picking route is provided with the integration of CBR in EOPS.

### **Data collection and storage module for e-commerce orders**

The handling of e-commerce customer orders in warehouses or distribution centres starts with end customers placing an order via the Internet. Delivery order information is then retrieved either directly from end-customers through setting up data synchronization, or from e-retailers who submit delivery requests to LSP in order for the orders to be processed and eventually shipped to the end customers. Therefore, this module includes a cloud database that collects and stores customer order details. Addressing the fact that an LSP deals with e-commerce cargoes for a number of e-retailers, in which the formats and details of the delivery order information sent by the e-retailer are not standardized, the cloud database serves as a pool for consolidating customer orders that need to be processed in the warehouse in a standardized and relational format. We name it an "E-order consolidation pool". Through data sorting and filtering, consolidated orders are displayed according to the item stock-keeping unit (SKU). The consolidated, sorted order details are regarded as the output of this module, and serve as the input of the next module for logically generating order picking lists.

### **Decision support module for warehouse operation postponement of e-commerce orders**

Details of the sorted and grouped orders stored in the e-order consolidation pool serve as the input of this module. An order picking wave will be generated by GA, in which a feasible solution of order picking is encoded as a string of integers that groups each stock-keeping units (SKUs) into a specific batch. The string of integers, as shown in Figure 2, is the order picking solution which identifies which particular SKUs are assigned to a picking batch. The



chromosome in Figure 1 groups the first and fourth SKU to picking batch 1, second and sixth SKU to picking batch 2, and the seventh SKU not assigned to any picking batch. To minimize the travel distance of each picking, the fitness function, i.e. the objective function, is defined as:

$$\text{Fitness function} = \text{Min} \sum_{k \in K} \sum_{i \in N} \sum_{j \in N} \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \times R_{ij}^k$$

The notation of the proposed model in EOPS is shown in Table 2. With the constraints, including picking capacity (in weight and volume) of the order-picker, special handling requirements (e.g. some SKUs cannot be picked simultaneously) and zoning preferences of each order-picker, being formulated, a two-point crossover method is used to produce offspring, followed by mutation and fitness evaluation, until meeting the stopping criteria. The output of Tier 1 is a set of order picking lists that outlines the combinations of SKUs to be picked in the batch. To further streamline the actual process in the warehouse, the details of each picking list serves as an input to Tier 2 of this module to generate the suggested picking sequence of the items outlined in the picking list, enabled by the use of CBR engine.

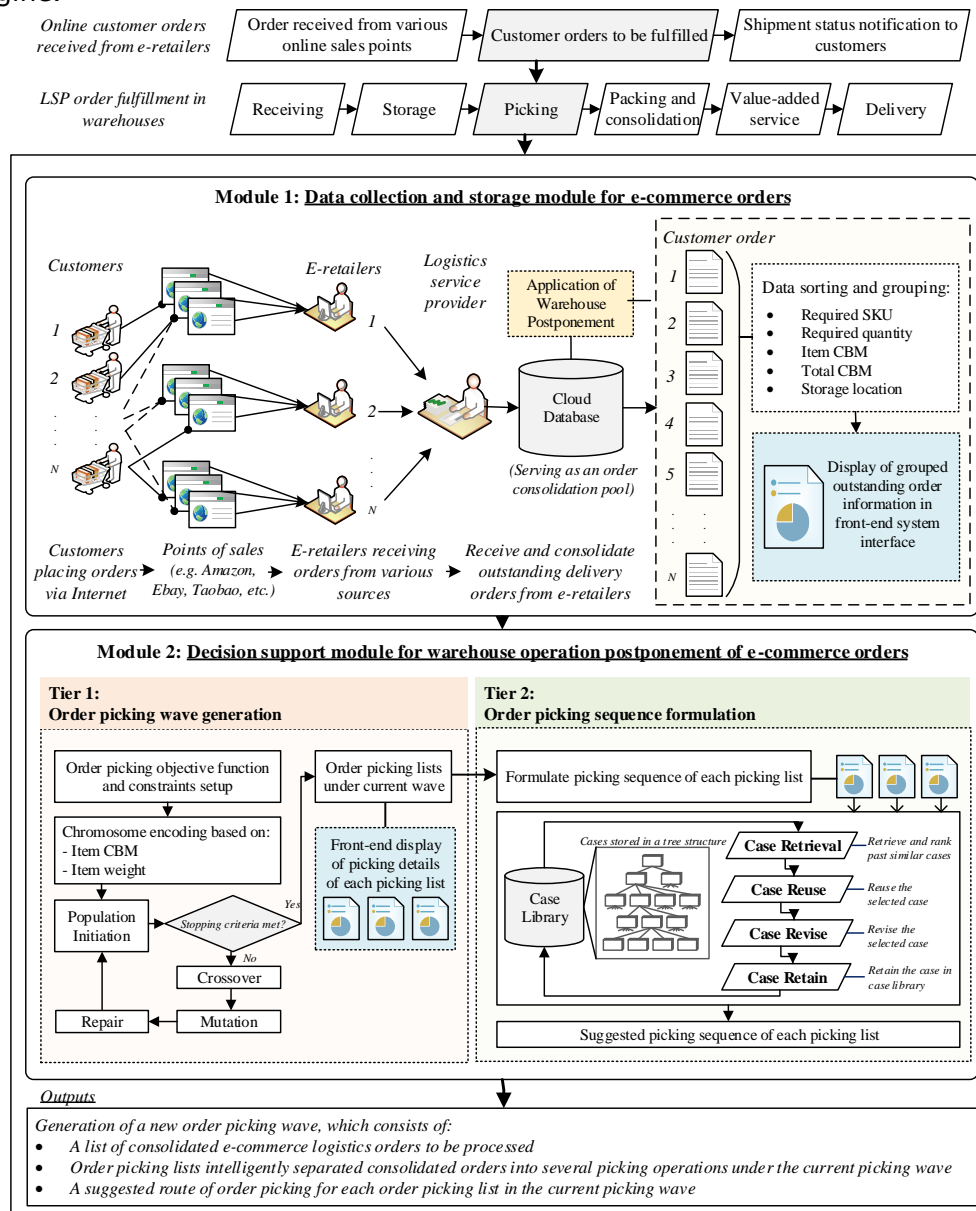


Figure 1. Architecture of EOPS

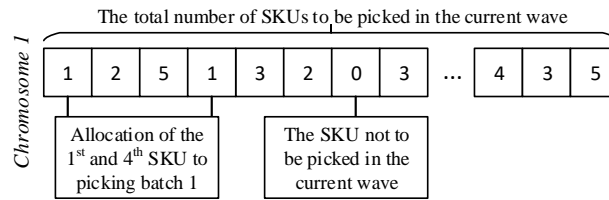


Figure 2. Chromosome encoding for order picking batch allocation

Table 2. Notation table for algorithm used in Tier 1 of EOPS

Notation definition	
<b>K</b>	Index set of all order-pickers, $K=\{1,2,...,k\}$
<b>N</b>	Index set of all storage location, $N=\{1,2,...,n\}$
<b>k</b>	Index for order-picker
<b>i, j</b>	Index for storage location
<b><math>x_{i,j}</math></b>	x-coordinate of storage location i or j
<b><math>y_{i,j}</math></b>	y-coordinate of storage location i or j
<b><math>R_{ij}^k</math></b>	Equals to 1 if order-picker k travels storage location i and j; otherwise 0

## CASE STUDY

ABC company is a Hong Kong-based third-party logistics service provider offering B2B total logistics solutions that cover a wide range of logistics and distribution services, such as warehousing, picking and packing, labelling, and shipping etc. As ABC has started handling e-commerce goods, operators experienced operating inefficiency in the 500,000 sq. ft. warehouse due to the tight schedule for order delivery and increased complexity of e-commerce order handling requirements. To improve the capability of handling e-commerce goods, the prototype of EOPS is deployed in ABC company. Figure 3 shows the user interfaces of EOPS implemented in the case company. All pending e-commerce orders are consolidated in "E-order Consolidation Pool". The order details are retrieved from the warehouse management system (WMS) of the case company. Warehouse manager can generate order picking lists in EOPS by running GA, which is executed in the back-end of the system. Once order picking lists are generated, the user can obtain the details of each order picking list in the next user interface. A picking sequence for each picking list can be formulated using CBR in Tier 2 of EOPS. The results are displayed in the final user interface, which are printable for order pickers to perform actual picking operations accordingly.



Figure 3. User interfaces of EOPS

## RESULTS AND DISCUSSION

With the pilot study being undertaken in the case company for system validation, this section discusses the results of the implementation of EOPS, and are discussed based on two key performance indicators (KPI) of order picking operations. They are: the average throughput rate and the average travel distance. Based on the results of the above KPIs, a significant improvement in the internal order handling efficiency of e-commerce orders is found. Before the introduction of EOPS, e-commerce orders are processed immediately once they are received. As shown in Table 3, the average throughput rate, or the cycle time of completing an order-picking operation for an e-commerce order is 12 minutes. The total travel distance of each e-commerce order is 142 meters on average. With the implementation of EOPS, the "E-order consolidation pool" acts as a buffer that groups the outstanding orders for batch processing. This enables the warehouses to reallocate resources to manage other operations until an order picking wave, comprised of a group of orders separated into several picking lists, is released from EOPS. On average, the throughput rate of handling an e-commerce order becomes 5 minutes, a 58% reduction in the required time for handling order picking operations for an incoming order. The travel distance is reduced to only 60 meters, also experiencing a 58% reduction. The saved time and travel distance enables the reallocation of human resources and equipment usage, as well reducing the operating costs in order-picking operations.

Table 3. A before-and-after comparison of order picking performance in case company

<b>Without EOPS</b>	<b>Measurement</b>	<b>With EOPS</b>
12 minutes	<b><i>Average throughput rate per e-commerce order</i></b>	5 minutes
142 meters	<b><i>Average travel distance per e-commerce order</i></b>	60 meters

## CONCLUSIONS

The warehouse order picking operation is one of the key typical categories of warehouse processes which has received much attention by industry practitioners and researchers. Previous studies proposed various types of techniques for aiding decision-making in the aspect of order picking. However, they rarely took the e-commerce logistics operating environment into consideration, making them impractical for tackling the current warehouse operational problems. Under the emerging e-commerce business environment, logistics service providers must be capable in managing discrete, fragmented and small lot-sized e-commerce orders within a tight schedule. Therefore, considering the e-commerce logistics operating environment as the core focus, this study proposes a decision support system as an application of "Warehouse Postponement", a concept addressing the essence of streamlining warehouse handling operations of e-commerce cargo by means of delaying warehouse process execution until the last possible moment. The proposed system incorporates cloud database management and serves as a pool for consolidating outstanding delivery e-orders; a genetic algorithm for logically splitting consolidated orders items into several order picking lists under a single wave of operation; and case-based reasoning for route planning in a particular warehouse storage location.

A prototype of the proposed system is implemented in a case company which handles e-commerce delivery orders. A before-and-after comparison reveals that significant improvements are found with the integration of the proposed system into the current order picking operations. By postponing the order handling process and consolidating outstanding delivery orders for processing in waves, the average throughput rate per e-commerce order and the average traveling distance of each e-commerce order have been drastically reduced. Therefore, the proposed system, which serves as a kind of disruptive technology that re-engineers and re-designs the e-commerce order handling process in warehouses and distribution centres, enhances the capability of logistics service providers in managing their e-commerce logistics business. More importantly, not only does the postponement of e-commerce order handling with the introduction of the proposed ICT solution streamline the operation of a single party, it also improves the overall last-mile

e-commerce order handling and distribution efficiency along the entire supply chain and distribution network from the root cause of the bottleneck of e-commerce order handling inefficiency, that is, the warehouse internal operations. In turn, this new approach brings benefits in supply chain efficiency improvement and excellence for e-commerce businesses, and encourages researchers to further develop decision support solutions for streamlining e-commerce order handling processes.

## ACKNOWLEDGMENTS

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# **STUDY ON THE METHODS OF REDUCING REDELIVERIES AND COLLECTING NECESSARY DELIVERY DATA**

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## **Abstract**

### **Purpose of this paper:**

The expansion of online shopping is increasing demands for BtoC home delivery. In Japan, about 20% of packages have to be redelivered because the receivers are absent at the time of the first attempted delivery. Although home delivery lockers are being installed at stations and commercial facilities, many still want to receive their packages at home. This paper assumes that packages are delivered to homes, and proposes a delivery method that would reduce redeliveries due to the receiver's absence and also a method of collecting the delivery data needed for this purpose.

### **Design/methodology/approach:**

We have studied a redelivery reduction method by considering that a failure to hand over a package to its receiver in a delivery time window arises mainly due to inadequate sharing of information between the delivery company and the receiver. Thus, we consider that it would be effective for the delivery company to collect daily delivery data and provide potential receivers with information derived from those data. In addition, we have studied a method of collecting delivery data using a Bluetooth Low Energy (BLE) beacon, which is an effective means for last-meter connection for IoT.

### **Findings:**

From this study, we have concluded that the number of redeliveries can be reduced by collecting and accumulating data on required traveling time between pairs of points on a delivery route over a certain period, and providing the potential package receiver in advance with information about the time window in which his or her package is likely to be delivered, i.e., the "arrival probability distribution." We have also studied how to collect data on traveling time and concluded that the following mechanism would be effective. Each delivery driver has a BLE beacon terminal (IoT device). It is connected to the smartphone (IoT gateway) of the receiver when his or her package is handed over to him or her so that delivery information can be uploaded to a server in the network.

### **Value:**

We can find no mention in any related literature of providing package receivers with an arrival probability distribution in advance or a mechanism of collecting delivery data by having delivery drivers carry BLE beacons (IoT). These are new ideas. Since this mechanism is similar to Point-of-Sale (POS), we call this mechanism "Point-of-Delivery (POD)." Data collected using a POD system can not only be used to reduce redeliveries but also be analyzed to improve a last-mile delivery service.

### **Research limitations/implications:**

The proposed methods on how to reduce the number of redeliveries and collect delivery data are still at the conceptual phase. We will incorporate these methods into a system and conduct feasibility tests to confirm their effectiveness.

## **1. INTRODUCTION**

### **1.1 Background**

The expansion of online shopping is increasing demand for BtoC home delivery [1][2]. In Japan, about 20% of home delivered packages have to be redelivered because the receivers are absent at the time of the first delivery [3]. Since this is a serious problem, both the national government and interested companies are working to reduce redeliveries. A major countermeasure is to enable the receivers to get their packages from home delivery-dedicated lockers installed at convenience stores, railway stations or commercial facilities. However, many people want to receive their packages at home. According to a questionnaire survey conducted in 2015, the places where people want to receive their packages are: home (86.5%), convenience store (35.3%) and dedicated lockers (14.8%).

## 1.2 Purpose of this paper

This paper looks at the state of redeliveries and at measures taken in Japan to reduce them. It focuses on cases where people receive packages at home, and analyzes the causes for redelivery, namely causes for mismatches between the time when the receivers are at home and the time when the delivery driver arrives. The paper proposes a method for reducing such mismatches. It further presents how it can be implemented, and proposes an IoT-based collection of delivery data, which are needed by the proposed method.

## 1.3 Research methodology

Mismatches in delivery time occur due to inadequate sharing of information between the delivery company and the receiver. We consider that mismatches can be reduced by providing the receiver with information about the expected delivery arrival time in advance. We propose that the delivery company provide information about exactly when during the delivery window the package is likely to arrive, namely the probability distribution of the arrival time. This method takes into consideration progress in IoT-related information technology, such as Bluetooth Low Energy (BLE) beacons, smartphones and Big Data analyses.

A well-known measure to reduce redeliveries is to install home-delivery-dedicated lockers. There are studies related this measure [4]. A measure that enables the receiver to get packages at home is to provide the receiver in advance with information about the delivery window and the package tracking record. A method of estimating the probability of a customer being at home by mining his/her electricity consumption data has also been proposed [5]. Regarding implementation technologies, use of a beacon to check the arrival of a package is known [6]. However, to the best of our knowledge, there have been no papers on providing the receiver with an arrival time probability distribution, which is calculated from past delivery records, or papers on using BLE beacons.

## 2. CURRENT STATE OF REDELIVERY AND MEASURES TAKEN TO REDUCE REDELIVERIES

### 2.1 Current state of redelivery

The result of a survey conducted in December 2014 on major home delivery companies in Japan is shown in Table 1 [3]. The result for all areas shows that about 20% of packages are redelivered. A separate result shows that, even if the receivers had specified the delivery window, about 17% (127,587) of all packages (749,851) were redelivered [3].

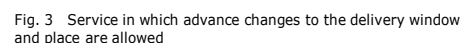
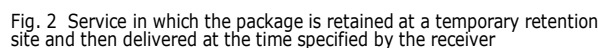
<i>Item</i>	<i>All areas</i>	<i>Single persons in urban areas</i>	<i>Single-family houses in suburban areas</i>	<i>Rural areas</i>
Total number of packages	4,136,887	1,777,732	2,035,861	323,294
Delivered the first time	3,328,088	1,394,407	1,661,388	272,293
Redelivered	808,799	383,325	374,473	51,001
Ratio of redelivery	0.196	0.216	0.184	0.158

Table 1 Current state of redeliveries (Source: MLIT, Japan)

Fig. 1 shows different cases of delivered packages being received. It is expected that redelivery occurs most frequently in Case a (bold line) in which packages are delivered to homes while the receivers are absent and they cannot be delivered to alternative places.



Online shops and home delivery companies are taking various measures to reduce redeliveries. Such measures are shown in Table 2. Examples of Measure (a2) [8] and

Table 2 Measures to reduce redeliveries and their features

Measure (c1) [9] are shown in Figs. 2 and 3, respectively. In Fig. 2, the delivery company brings the package to a temporary retention site located near the receiver. After that, the receiver can specify any delivery window between 18:00 and 24:00 and receive the package. Packages are delivered from the retention site to individual homes not by the home delivery company but by registered crowdsourced individuals. In the service shown in Fig. 3, the delivery company notifies the receiver of the delivery date, time and place by email or via an SNS. If the receiver finds that he/she cannot receive the package at the notified time, he/she can change the delivery time and place. The delivery company delivers the package at the changed time and place. Because of this, the ways packages can be received are becoming more varied.

### 3. CAUSES FOR MISMATCHES IN PACKAGE RECEPTION TIME AND MEASURES TO REDUCE MISMATCHES

#### 3.1 Causes for mismatches

Redelivery of a package happens when the receiver is absent during the delivery window that he/she has specified. This situation is referred to as a "mismatch in package reception time." Such mismatches occur because the home delivery company's assumption is at odds with the receiver's psychological disposition regarding waiting for delivery (Fig. 4).

(i) Delivery company's assumption: The delivery company assumes that the receiver will be at home any time during the receiver specified delivery window. The company cannot predict exactly when during the delivery window it will deliver the package.

(ii) Receiver's psychological disposition: The receiver waits for the package hoping that it will arrive while he/she is at home. Without information about the exact delivery time, he/she may leave home depending on the particular situation.

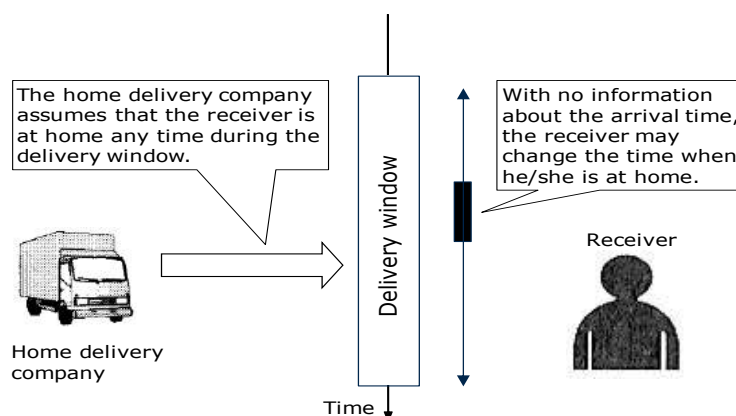


Fig. 4 Mismatch in package handover between the home delivery company and the receiver

#### 3.2 How to reduce mismatches

To reduce mismatches in the conception of delivery time between the two parties, either of the following measures can be taken:

Measure A: The delivery company obtains information about whether the receiver is at home, and delivers the package while he/she is at home.

Measure B: The receiver obtains information about exactly when the package will arrive, and stays at home at that time.

Measure B is more implementable than Measure A for the following reason. In Measure A, even if the delivery company obtains information about whether the receiver is at home, it is generally not easy for the company to come to the receiver's home exactly when the receiver is expected to be at home. On the other hand, in Measure B, it is relatively easy for the receiver to be at home at the time when the home delivery company says it will deliver the package.



Measure B requires the delivery company to inform the receiver of when in the delivery window the package will be delivered. The company calculates the arrival probability distribution from the past delivery record data and presents it to the receiver. This is expected to raise the probability that the receiver is present when the package is delivered. A method of implementing Measure B is discussed below.

## 4. HOW TO IMPLEMENT MEASURE B

### 4.1 Assumptions

We assume the following:

- (i) The receiver gets the package at home.
- (ii) The receiver gets the package during the specified delivery window (2 hours or longer).
- (iii) The delivery company brings the package to the receiver. No crowdsourced drivers are involved.

### 4.2 Implementation of Measure B

Measure B is shown schematically in Figs. 5 and 6. As shown in Fig. 5, let  $i$  and  $j$  ( $1 \leq i, j \leq n$ ) be two points on the daily delivery route. Let  $\tau(i, j)$  be the required time between  $i$  and  $j$ . The company collects  $\tau(i, j)$  for all points on the delivery route. Here,  $i$  is the starting point and  $j$  is the arrival point. They are not the addresses of receivers. They are cell numbers. The service area is divided into cells (meshes) (for example, each cell can be a 500 m square). Let  $n$  be the total number of cells in the service area.  $\tau(i, j)$  is defined as follows:

$$\tau(i, j) = \text{travel time from } i \text{ to } j + \text{handling time at } j$$

$\tau(i, j)$  is collected during daily delivery routine and stored in the required time management server. If this data collection is continued, the distribution of the required time between  $i$  and  $j$ ,  $PD(i, j)$ , can be calculated. After a sufficient amount of data is accumulated in the server, it becomes possible to provide the receiver with the arrival time probability distribution. Fig. 6 shows an example of the delivery route and calculation of the arrival

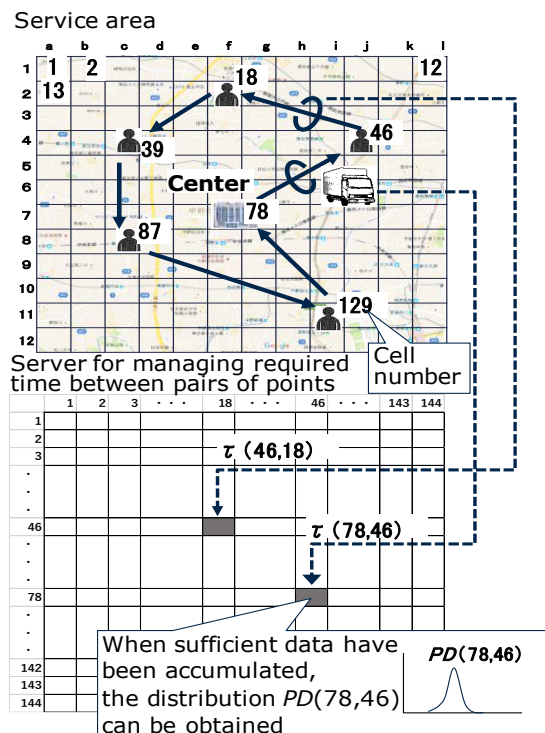


Fig. 5 Collection and accumulation of data on travel time between pairs of points

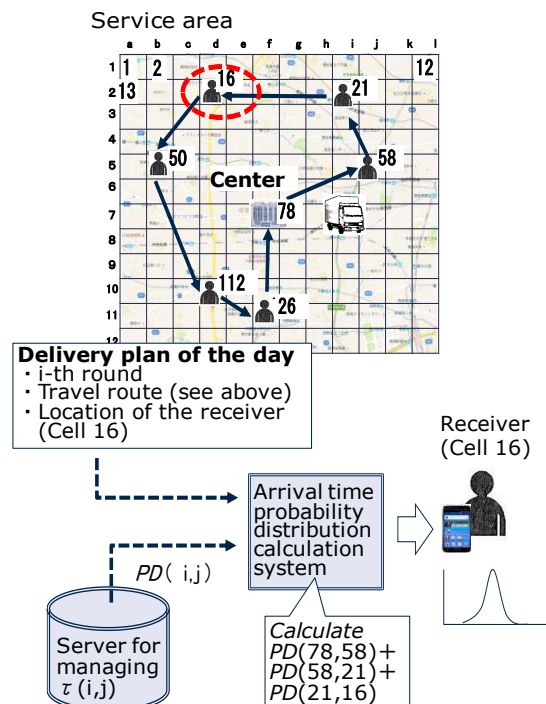


Fig. 6 Provision of the arrival time probability distribution to the receiver

time probability distribution. When the start time at the center and the delivery route are determined, the arrival time probability distribution calculation system adds up the required time distribution,  $PD(i, j)$ , of all the two-point pairs on the route up to the receiver (located at cell 16) to calculate the arrival time probability distribution for the receiver,  $\Sigma PD(i, j)$  (all  $i$ - $j$  pairs on the route from the center to cell 16). The delivery company provides the receiver with this  $\Sigma PD(i, j)$  in advance of delivery. This increases the probability at which the receiver is at home when the package arrives.

### 4.3 IoT-based data collection

The method of collecting and storing the required time between two points,  $\tau(i, j)$ , as shown in Fig. 5, is discussed below. Collection of delivery data can be facilitated by IoT. BLE beacons (IoT devices) and smartphones (IoT gateways) are useful for the last meter connection in IoT. While the use of beacons to confirm delivery completion is well known [6], we use BLE beacons and smartphones for data collection.

#### 4.3.1 Patterns of connections between an IoT device and an IoT gateway

In general, an IoT device, which is installed in an object or at a fixed point of an area, is connected to an IoT gateway via wireless communication, and through the gateway to the Internet. If the positions of both an IoT device and an IoT gateway are fixed, they are constantly connected to each other. If one of them or both of them are mobile, they may

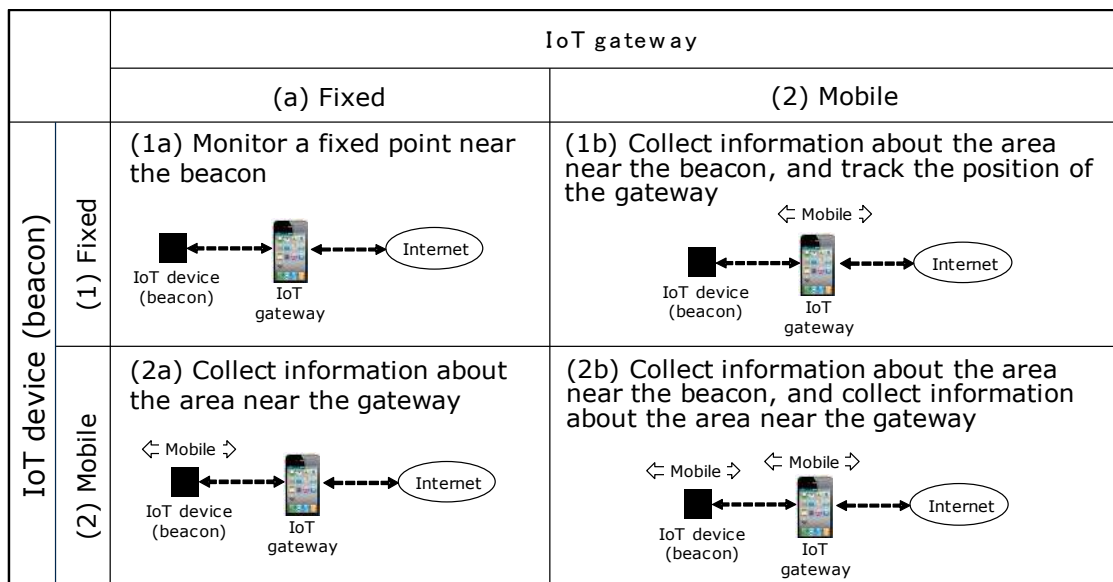


Fig. 7 Patterns of connections between an IoT device and an IoT gateway and their applications

be connected sometimes but disconnected at other times. Fig. 7 shows conceivable connection patterns.

In Pattern 1a, both the IoT device and the IoT gateway are at fixed locations and are constantly connected to each other. This pattern may be used to monitor, via the gateway, the ambient conditions, such as tilt, temperature, humidity and illuminance, of the object that has the IoT device. In Pattern 1b, the IoT device is fixed but the IoT gateway is mobile, and thus they are connected to each other at one time but disconnected at other times. This pattern may be used to collect information about the state of the object that has the IoT device, and the state of its surroundings at the time when the IoT gateway is connected to the IoT device. It may also be used to track the position of a mobile IoT gateway that is simultaneously connected to a number of IoT devices. In Pattern 2a, the IoT gateway is at a fixed position but the IoT device is mobile, and thus they may be connected or disconnected alternately. This pattern may be used to send information about the surroundings of the IoT gateway to the Internet at the time when the person or object that

has the IoT device comes into close proximity with the IoT gateway. In the last pattern, Pattern 2b, both the IoT device and the IoT gateway are mobile, and they may be connected to each other or disconnected consecutively. This pattern may be used to collect information about the state of the person or the object that has the IoT device and the conditions of the person's or object's surroundings at the time when the person who has the IoT gateway comes into close proximity with the person or object that has the IoT device. Alternatively, it can be used for the IoT gateway to send information about its own state and surroundings to the Internet at the time when the person who has the IoT device comes into close proximity with the person who has the IoT gateway.

#### 4.3.2 IoT-based data collection method

The required time between two points can be calculated if information about when the delivery driver came into the vicinity of the receiver. This information can be obtained by making either the delivery driver or the receiver have an IoT device (BLE beacon) and the other party an IoT gateway (smartphone) so that this information can be sent to the server. Since most receivers have smartphones, it would be reasonable that the delivery driver has an IoT device, and the receiver an IoT gateway. The IoT device held by the driver moves around, and thus Pattern 2a or 2b in Fig. 7 applies.

An example of collecting information about the required time between two points is shown in Fig. 8. The following is assumed:

- (i) The delivery driver has a BLE beacon (IoT device), which periodically transmits a radio beacon over a distance of several meters.
- (ii) The receiver has a smartphone (IoT gateway), which has the ability to perform BLE communication and with an app dedicated to the home delivery service.

As shown in Fig. 8, (1) the delivery person takes a course towards the receiver's home. At this stage, the driver's BLE beacon is searching for a device to which it can be connected. Eventually, (2) the driver reaches the receiver's home. If the receiver is at home, the driver's BLE beacon is automatically connected to the receiver's smartphone. The smartphone serves as an IoT gateway for a connection between the driver's BLE beacon and the Internet. (3) It sends information received from the BLE beacon (e.g., information

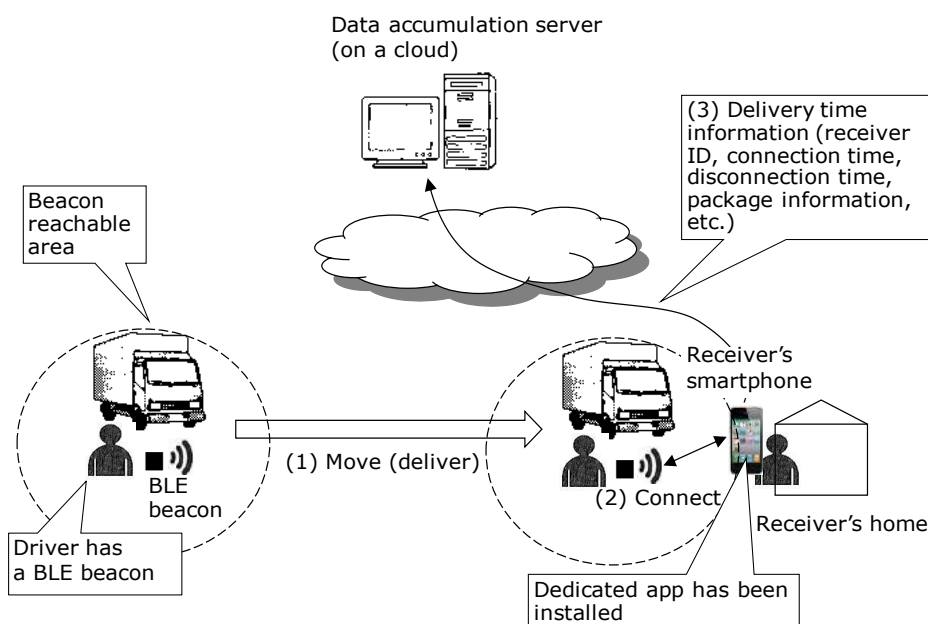


Fig. 8 Method of collecting delivery data (POD system)

about the package), the receiver ID, the time when the smartphone is connected to the

BLE beacon and the time when it is disconnected, to the data accumulation server in the cloud via the Internet.

In this way, not only information required for calculating the required time but also all items of information that may prove useful in later analysis are collected. Since this mechanism is similar to that of the POS (point of sale) systems adopted by convenience stores and supermarkets, we call it POD (point of delivery). A large amount of data will be accumulated in the server to become Big Data. Analysis of the Big Data will be useful for improving the service. The case where the receiver gets the package at home corresponds to Pattern 2a in Fig. 7 while the case where the receiver gets the package at a location away from his/her home corresponds to Pattern 2b.

#### **4.3.3 Issues for commercial implementation**

Before we can implement the proposed system and provide the service, it is necessary to study the following:

- (i) It is necessary to design details 1.) of the server for managing the required time between two points, 2.) of the system for calculating the expected arrival time, and 3.) of the procedure for providing information to the receiver.
- (ii) It is necessary to verify the effectiveness of the proposed system by actually implementing the system and operating it on a trial basis.
- (iii) For future development of the system, it is necessary to study how to use data collected by POD effectively.

#### **5. CONCLUSIONS**

This paper has proposed a method of reducing mismatches between the home delivery company and the receiver regarding his/her presence at home during the receiver specified delivery window for cases where receivers get packages at home. This method collects and stores data on the required time (travel time plus handling time) between two points on the delivery route on a daily basis, and provides the receiver with information about exactly when during the delivery window the package is most likely to be delivered. This information is calculated from the accumulated data.

Looking forward, we will study the issues listed in Section 4.3.3.

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# TOWARDS A SECURED TRACEABILITY SYSTEM FOR CLOSED-LOOP TEXTILE SUPPLY CHAINS

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## ABSTRACT

Textile and clothing (T&C) industry is characterised by complex and extensive supply chain involving various stakeholders dealing with diverse raw materials. Owing to these complexities, the textile supply chain is facing numerous challenges like, counterfeit products, limited information sharing, ineffective recycling/reuse of textile products, unethical practices and interrupted information flow. As a result, a secured traceability system that can integrate the whole value chain, record, store, and track / trace all supply chain activities, make it more transparent and at the same time safeguard it from unauthorized access, has become a prime requirement for the T&C industry. In this context, the current study conducts a literature review to identify the generic requirements of traceability and in context of T&C closed-loop supply chain (CLSC). It further evaluates the role and key requisites of a cryptographic tag for textiles product, as an additional measures/parameter to secure the traceability system and prevent unauthorised access. Finally, the paper draws on key characteristics of such cryptographic tag for textile CLSC and lay down the tentative methodology that would be followed in the future research for development of a complete secure traceability system. It is anticipated that such secured traceability system can prevent counterfeits, data leakage, bring transparency and automate the reverse logistic process.

## INTRODUCTION

Latest technological advancement, increasing consumer demands and reduced product lifecycle have boosted production throughout the world. Due to this, raw material demands are increasing and available landfills are quickly filling up, creating an environmental imbalance. This crisis has made the institutes like governments, authorities and world leaders to force the industries to take up sustainable initiatives in their supply chain and adapt practices leading to effective use, reuse and recycle of product and material (Su- Yol Lee, 2008). Proper handling of waste and hazardous substance and safe and secure utilization of tangible and intangible resources had become mandatory industrial norms (Misra and Pandey, 2005).

Closed-loop supply chain and reverse logistics are such supply chain practices adapted by numerous industries to meet their sustainability goal. Closed-loop or circular supply chains are economic or distribution system supporting the concept of cradle to cradle and thus encompass both forward (fabricator to consumer) and reverse (consumer to fabricator) flow of material or product (Guide et al., 2003). In an effective closed-loop supply chain system sold products after their usable life are taken back from the customer, recycled, reused or remanufactured in order to recover additional value resulting in environmental and/or economic benefits. Nevertheless, implementing the same in a real industrial scenario has its

own challenges in addition to that of the forward or linear supply chain (Guide et al., 2003). Moreover, reverse logistics have shown to be less economically beneficial and complex process in previous research. The operations involved in reverse logistic complicate managerial decision making process regarding collection and inventory management due to high uncertainty in return rates (Zhu and Sarkis, 2004).

In this direction, supply chain integration through effective information sharing technologies and collaboration has proven to be useful solution to counter the challenges of CLSC (Nativi and Lee, 2012a). Timely access of correct information related to location, status and condition of product within the supply chain can reduce the uncertainty in monitoring the return (Jayaraman et al., 2008). Substantial research has been carried out in past decade to develop such information sharing technologies and systems for CLSC. An integrated supply chain with secured traceability system using unique identifier tags (cryptographic tags) is one such example which finds wide application in miscellaneous industries, such as electronics, food and automobile for tracking, tracing of products and effective information sharing (He et al., 2008). Information sharing with integrated supply chain system using these tags helps in coordinating inventory policies, prevents counterfeit, automated sorting, segregating and recycling, recall management, trend forecasting, transparency and ensure product quality and consumer safety in CLSC. These tags act as a unique identifier which links each product to product database which records and stores product related data (Agrawal et al., 2016).

In case of T&C industry, secured traceability has emerged as an important concern due to its opaque and complex distribution system that has led to numerous issues (Corbellini et al., 2006). Brands and retailer are suffering huge losses due to counterfeits products and unethical practices of suppliers pertaining to limited or no traceability. Consumers and authorities are constantly demanding for a more transparent and sustainable supply chain. None or limited information regarding product raw material composition at recycling stage, results in ineffective sorting and recycling of product. Additionally, widely used and available technologies in market like, RFID tags or barcodes associated with textile products, (acting as traceability links) can easily be cloned and are detachable. These tags can be exchanged with duplicate ones or can be removed after the purchase or deactivated (RFIDs) at point of sales to avoid privacy issues or discomfort, thus limiting their application for counterfeiting and reverse logistic purpose.

In this context, the present study reviews the existing literature to explain the concept and need for traceability implementation in the textile CLSC. It further discusses the requirements for securing the traceability system and preventing unauthorized access, by proposing the development of a uniquely identifiable cryptographic tag. It should be noted that this study is part of ongoing research work that aims at exploring, understanding, developing and recommending a secured traceability system for safe and effective information sharing in data-driven textile CLSC. It is anticipated that such a system will lead to transparency, automatic product authentication, sorting, segregating (during reverse logistics activities), tracking and tracing of product by each stakeholder of the supply chain using cheaper and widely available technologies (e.g. smart phone for customer).

## **LITERATURE REVIEW**

A brief literature review on the generic concept of traceability, its importance and need, and in relation to textile CLSC is presented here. This further motivates the proposed development of a cryptographic tag as unique identifier for eradicating

counterfeits, unauthorized access and unsecured information sharing, as derived from the literature review to realize the concept of secured traceability in textile CLSC.

### Traceability - Concept

Traceability as defined by International Organization for Standardization (ISO) is *"the ability to identify and trace the history, distribution, location, and application of products, parts, materials, and services. A traceability system records and follows the trail as products, parts, materials, and services come from suppliers and are processed and ultimately distributed as final products and services"* (Henrik Ringsberg, 2014). Some of the prominent advantages of traceability are tracking, tracing of product, and effective information sharing and resource management among different stakeholders in supply chain and with government authorities. Traceability acts like a foundation for sustainable development and supports the triple-bottom line of sustainability (Kumar et al., 2017a). In past decade, significant research had been undertaken in field of traceability in food, chemical and medicines supply chain due to the serious health concerns involved with them (Henrik Ringsberg, 2014 ; Sun et al., 2014) .

### Traceability- Need

Traceability system has numerous advantages. As explained before, it is prerequisite for effective management of production, quality, logistic and information. In the current data driven world, traceability also act as a base supporting the concepts of 'Internet of Things' (IOT) and align with Industrie 4.0, the forth industrial revolution, when the manufacturing will be more smart with automatic information exchange within the production system and throughout the supply chain (Abramovici et al., 2015; Stoten, 2014). However, in case of T&C industry the concept of traceability and closed-loop supply chain is still quite nascent because of its diverse and complex supply chain and cheap product cost. The production sites are majorly found in developing countries (like Bangladesh, Vietnam etc.) and consumer base in developed one (like the EU and the US) resulting in huge geographical gaps and more opaque supply chain system. All these have led to unethical sourcing and production, counterfeits products, product recalls and unhealthy supply chain practices giving rise to constant demand for transparency through secure traceability system by the customer (Kumar et al., 2017b). To better explain the generic need of traceability and also in textile CLSC an exploration of the different parameters effected or improved by traceability discussed in literature are compiled in Table 1 with scientific and non-scientific references.

<b>Parameters</b>	<b>Effect of Traceability</b>	<b>Ref. (Textile)</b>	<b>Ref. (Others)</b>
<b>Supply Chain Transparency</b>	<ul style="list-style-type: none"> <li>Information about supplier names, sustainability conditions at suppliers, and buyers' purchasing practices.</li> <li>Promote ethical buying practices</li> <li>Record and follow all the product history and process thus leading to more transparent system.</li> </ul>	Egels-Zandén et al., (2015), Kumar et al., (2017a), Doorey, (2011), Strähle and Merz, (2017)	Kraisintu and Zhang, (2011), (Nel) Wognum et al.,(2011)
<b>Information Management</b>	<ul style="list-style-type: none"> <li>Useful information acquisition, storing, sharing/distribution among authorized stakeholders and ultimately deleting or archiving.</li> <li>Promote concepts of Big Data and Internet of things.</li> <li>Management of data or information related to product and helpful in</li> </ul>	Kumar et al., (2017b), Kumar, (2017), Cheng et al., (2013), Alves et al., (2013), Legnani et al.,	Henrik Anders Ringsberg and Vahid Mirzabeiki, (2014), Bechini et al., (2008), Ming Juan Ding et

	understanding the link between all aspects of a product lifecycle.	(2011a)	al., (2014), Tyler R. Morgan et al., (2016)
<b>Logistic Management (Tracking)</b>	<ul style="list-style-type: none"> <li>Tracking, tracing, planning and controlling an efficient and effective flow and storage of goods between different supply chain nodes.</li> <li>Prevent counterfeits and theft in the supply chain.</li> <li>In reverse logistic, it can be useful for inventory policies among decentralized actors in supply chain.</li> </ul>	Nayak et al., (2015), Legnani et al., (2011b), Azevedo et al., (2014), Alves et al., (2013)	Henrik Ringsberg, (2014), Bechini et al., (2008)
<b>Product Origin / "Made in"</b>	<ul style="list-style-type: none"> <li>Information more than just the country of origin can be retrieved.</li> <li>Location of raw material supplier, sub-industries and all other supply chain actor.</li> </ul>	Strähle and Merz, (2017), (Alves et al., (2013)	(Peres et al., (2007), (Loureiro and Umberger, (2007)
<b>Product Composition and Recycling</b>	<ul style="list-style-type: none"> <li>Information about quantity and type of raw material used for manufacturing of the product.</li> <li>Important factor during product purchase.</li> <li>Useful for effective recycling of product.</li> <li>Actual Life Cycle Analysis data</li> </ul>	(Kumar et al., (2017a), (Palm et al., (2014), (Pigni et al., (2007)	(Wyld, (2010), (Nativi and Lee, (2012b)
<b>Quality and Recall Management</b>	<ul style="list-style-type: none"> <li>Traceability information ensure quality consistency in production or services.</li> <li>Quality planning, assurance, control and improvement.</li> <li>Origin of defect or bad quality can be traced.</li> <li>Useful for organic, quality or green certification.</li> </ul>	Kumar, (2017), Cheng et al., (2013), Pigni et al., (2007)	Henrik Anders Ringsberg and Vahid Mirzabeiki, (2014), J. Oehlenschläger et al., (2006), Meuwissen et al., (2003)
<b>Production Management</b>	<ul style="list-style-type: none"> <li>Internal traceability (track and trace the product during production)</li> <li>Prevents missing of parts during assembly process.</li> <li>Useful for just in time production, planning and control.</li> <li>Information useful for remanufacturing of used product</li> </ul>	Siu Keung Kwok and Kenny K.W. Wu, (2009), Legnani et al., (2011a)	Henrik Ringsberg, (2014), Bechini et al., (2008), Jansen-Vullers et al., (2003)
<b>Unique Identification</b>	<ul style="list-style-type: none"> <li>Prevent counterfeits and smuggling.</li> <li>Helpful for custom and border security.</li> <li>Brand Authentication and protection.</li> </ul>	Agrawal et al., (2016), Corbellini et al., (2006), Kumar, (2017)	Sun et al., (2014), Bechini et al., (2008), Turcu et al., (2013), Henrik Pålsson and Ola Johansson, (2009)
<b>Marketing</b>	<ul style="list-style-type: none"> <li>Traceability information act as a unique selling point (USP).</li> <li>Promote brand image</li> <li>Sales Forecasting and management</li> </ul>	Kumar, (2017), Guercini and Runfola, (2009)	Bechini et al., (2008), Roosen, (2003)



### **Towards a Secured Traceability system**

"Secured traceability is the ability to trace the lines of products a company releases on the market, while preventing attacks on the tracing system" (Fayolle et al., 2008). A secured traceability simultaneously safeguards the system from any external attack leading to data leakage, product piracy and unauthorized disclosure of shared information in addition to facilitating management of other traceability parameters. These security-related issues are gaining significant attention of customer as well as supply chain actors due to recent incidents of supply chain attack (Suhaiza Hanim Zailani et al., 2015). For example, Apple iPad minis worth 1.5 million US dollar were stolen from the JFK, New York airport USA in November 2012 due to information leakage within the supply chain. Similarly, Foxconn network was hacked and Foxconn's global sales managers contact details were stolen (Bhargava et al., 2013).

According to report by IBM on the "Security trends in the manufacturing industries 2016" (McMillen, et al., 2016), manufacturing sectors including textile, have huge potential threats from data attackers targeting their intellectual property and operations information. Moreover, counterfeits have always been an important concern especially for the T&C industry that, is suffering huge loss due to counterfeit product every year (Corbellini et al., 2006). These products not only damage the fashion brand image and economies but are also harmful for the consumer due to the inferior quality (Ekwall, 2009). Every year the custom and border security forces seize counterfeits products worth millions dollars however, their trades are almost uncontrollable due to their huge volume and numerous weak links in the textile supply chain. As per the report of European Union Intellectual Property Office Observatory, due to counterfeits product the T&C industry losses 9.7% of sales, 26.3 billion euro of revenue per year by the sector, 36300 direct jobs and 8.1 billion euro of revenue by government ("The economic cost of IPR infringement in the clothing, footwear and accessories sector," 2015). Another factor for secured traceability is the constant demand for transparency in textile supply chain by consumers and other authorities (Egels-Zandén et al., 2015). This has raised the critical issue for securing and safeguarding information sharing among the supply chain actors.

There are several method to address security issues in supply chain in order to develop secure traceability system (He et al., 2008 ; Guillermo Azuara et al., 2012). One of that is by developing a signature for each product based on its unique characteristics as in case of biometric identification system for human being. Thus, each product (SKU) will have a unique identity that cannot be copied onto other product and this identity code will act as a key to access the secured traceability system, prevent breaches in the lower level (between tag and reader). Another method being the secure data sharing using product checkpoints or collaboration strategies where well-defined information are shared within trusted party, until certain extent depending on the trust level and agreements, thus guaranteeing the security in data sharing e.g. the Circle of Trust concept (He et al., 2008). In case of textile CLSC there are numerous challenges in developing and implementing such system apart from the generic one. Therefore, the current study focuses on the first method related to development of cryptographic identifier and evaluate the key requisites for an ideal traceability tag for textile. The second method related to study of collaboration and information sharing based on "circle of trust" concept, type and extent of traceability information need to be shared among the different textile supply chain actor (mainly, customer, retailer and supplier) will be undertaken in future research.

### **Key Characteristics of a Textile Traceability Tag**

Aforementioned, an unclonable unique identifier in form of tag is key requirement to secure a traceability system. For application in textile CLSC an ideal textile traceability tags should have following characteristics:

- 1) Unclonable:** The major drawback with the existing tags like RFIDs and QR code are that, they can easily be copied and be replaced with a duplicate one, thus breaching the traceability system. Moreover, in case of cryptographic RFIDs the price of the tags is quite high and relatively expensive for low cost textile product. Therefore, an ideal solution will be using some economical, conventional textile process and encryption method to develop a cryptographic tag (Agrawal et al., 2016; Corbellini et al., 2006; Kumar, 2017).
- 2) Integrated with textile product:** Presently, the textile tags like bar codes and QR code are attached with some external means or are stitched to the product. They are detachable and are removed after purchase. Electronic tags like RFIDs are deactivated after or at the point of sale to prevent privacy issues. Thus these tags cannot be used during the reverse logistic process or recycling stage. Therefore, an ideal tag should be integrated in the textile product to avoid detachability issue and should not cause any privacy concern after POS (Kumar, 2017) .
- 3) Low cost and durable:** Mass produced textile product are generally inexpensive and an additional cost for slightly expensive tag will relatively increase the overall cost of the product. Therefore, it should be very low cost without effecting the overall product cost and should be durable against washing and abrasion (mechanical agitation) (Corbellini et al., 2006).
- 4) Easy readability:** RFIDs and some barcodes need additional devices for decoding purpose, so all actors of the supply chain, especially customers, cannot read the content. Therefore, an ideal tag should be easily readable and decoded using some readily available device (like smart phone) making the information accessible to all actor at any given time (Agrawal et al., 2016).
- 5) Uniform information content:** Presently there are different tags in market conveying different information to the customers. Some inform about the product composition, certification, origin country, Life Cycle Analysis (LCA) data etc. However, a research should be under taken to explore the ideal content of a tag taking into account the requirements of each supply chain actor.

## CONCLUDING REMARKS

The study reviews the existing literature to explain the concept and need of traceability and secured traceability in textile CLSCs. It further highlights the methods to secure the traceability system and explain the key characteristics requisite to develop such a textile based cryptographic tag. Future, research can be undertaken to:

- 1) Include textile industry perspective on traceability:** Find the Industries perspective and understanding about secure traceability. A survey will be done with different Swedish industries to know their understanding about the different traceability parameters obtained from literature, traceability incentive taken by them so far and future plans.
- 2) Explore more on how collaboration and Information sharing can ensure secured traceability:** As discussed earlier, one of the important aspects of traceability system is to have an effective collaboration and information sharing among all the actors of supply chain and build a circle of trust. Currently, the brands and the supplier in T&C industry do not have a clear understanding about the type and extent of information needed to be shared. Therefore, future research may explore what type of information the fashion brands and retailers think they should share with its upstream and downstream partners in order to be more transparent.
- 3) Develop cryptographic traceability tag:** As highlighted above, integrated cryptographic tags are key to develop a traceable multi-actor system. Future research may take into account the identified tag characteristics to develop physically new cryptographic tags.

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# PORT DATA MANAGEMENT SYSTEMS TO IMPROVE CAPABILITY

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## ABSTRACT

**Purpose:** A good port data management system can undoubtedly improve a port's operations and hence its competitiveness. This in turns affects the economic development of the city or region of the port. Given the fast changing environment globally, forecasting the container throughput of a port is thus of vital importance. Previous container forecasting models mainly adopt high-level domestic socio-economic data, such as Gross Domestic Product (GDP) and pervious year container throughput as the input data to forecast the container throughput. But limited research has incorporated external market or industrial data to forecast container throughput. This paper attempts to bridge this gap.

**Design:** This paper firstly proposes the Container Shipping Competitiveness Index (CSCI) as the external market data to represent the condition of international container shipping environment. Then, different forecasting models are employed to forecast port throughput with and without the index. More specifically, support vector regression, a machine learning approach, was included.

**Findings:** Forecasting accuracy with the CSCI is better than without it for all models of concern. Additionally, the machine learning approach outperforms other non-learning approaches, regardless of using the index or not.

**Value:** The contributions of this paper are twofold: (i) The proposed CSCI can help improve the forecasting accuracy, regardless of the choice of model. The effect is particularly obvious when the forecasting model is linear in nature; and (ii) In addition, the paper verifies that machine learning forecasting approach can outperform a number of traditional forecasting approaches.

**Practical implications:** The scheme proposed by this work will increase port economy development and port logistics competitiveness, and working efficiency. The port logistics and related stakeholders can benefit from understanding and analysing the data about port operations and regional economic situation. The proposed scheme can support port managers to make better decisions.

## INTRODUCTION

Port development is always coupled with urban economic development. Most importantly, the urban economic development can be promoted by the development of port [1, 2]. The shipping goods have been divided into different types based on the nature of cargo, such as dry bulk, petroleum, containerised cargo, and bulk and general cargo, and each category has its own types of product which is shown in Table 1 [3]. In these different types of cargo, containerised cargo is fit for intermodal transportation between different modes of transportation. The containerised cargo's transportation is able to increase the circulation velocity of the products, to reduce the circulation cost and to save the logistics labour [4]. Because of these characteristics mentioned above, containerisation has been becoming the most popular maritime logistics mode. Therefore, an effective container throughput forecasting model is able to assist port operations in making decision on investment scale, location of the berth and operation strategies, and so on.

<b>Dry Bulk</b>	<b>Petroleum</b>	<b>Containerised Cargo</b>	<b>Bulk and General Cargo</b>
Coal	Petroleum	Mechanical appliances	Mine material
Metallic mineral	Petroleum refined products	Chemical product	Steel
Grain		Nonferrous metals	Cement
		Agriculture and farming	Salt
		Light industry product	Wood
		Medical product	Non-metallic ore

Table 1: The structure of the port's throughput

At present, port logistics data has been utilised in diverse intelligent applications. For example, the competitiveness of different ports in China had been calculated by analytic hierarchy process and exploratory factor analysis [5]. The results demonstrated that the competitiveness of a port is highly related to the infrastructural investment followed by the involvement of foreign economic and tertiary industry development level. The importance of tertiary industry development on port development had also been studied by Gu and Wang [3], the outcomes also showed that the subdivision industry values under primary, secondary and tertiary industries are coupled to the port throughput. These influencing factors have been used to build a forecasting model. Autoregressive moving integrated moving average (ARIMA) is the most traditional and arguable the best time series forecasting model which had been applied in many fields. ARIMA is an effective forecasting model in short-term forecasting and uses target variable's historical data [6, 7]. For example, ARIMA had been used to forecast container throughput of the Ningbo Port [8]. ARIMA, however, only required historical data as the input variables. It is thus unable to capture the relationship between other factors and the target variable. Artificial neural network (ANN) and support vector regression (SVR) are two popular machine learning techniques which are able to capture such patterns from historical data and find the non-linear relationships between multiple input variables and the target variables. Different types of ANN and SVR are widely used in different fields to forecast the target variables [9-13], including container throughput [14, 15].

In the aforementioned forecasting methods, GDP and production value of secondary industry are commonly used as the input variables to forecast container throughput. In the research conducted by Gu and Wang [3], they divided port's throughput and GDP into different categories as shown in Table 1 and Table 2. By analysing the source of the containerised cargos, the study proved that the production value of subdivision industries under secondary industry is related to container throughput and also proved that primary industry and tertiary industry had some effects on container throughput as they affect the development of secondary industry. Therefore, the production value of subdivision industries can be used to forecast the container throughput.

<b>Primary Industry</b>	<b>Secondary Industry</b>	<b>Tertiary Industry</b>
Agriculture	Petrochemical industry	Service industry
Forestry	Textile industry	Transportation industry
Animal husbandry	Electrical appliance manufacturing	Storage
Fishery	Mechanical manufacturing	Postal service
		Financial industry
		Real estate

Table 2: The structure of GDP

Though the previous studies show the value of GDP and production value of secondary industry on forecasting of the container throughput, these two types of data can be treated as high-level domestic socio-economic data of the port, as these data are related to the development of the coupled city. However, the port's operation is related to not only the development of the coupled city, but also the international container shipping environment. Therefore, a new approach is required to integrate this parameter into the forecasting model. This paper firstly proposes the Container Shipping Competitiveness Index (CSCI) as the external market data to represent the international container shipping environment. And, then the proposed scheme adopts the subdivision industry values as the domestic data and the CSCI as the external market data into the forecasting model.

## RESEARCH METHOD

The yearbooks of Ningbo provide the historical container throughput of the Ningbo Port and the subdivision industries growth values. The top 20 container ports' throughputs between 2004 and 2015 are collected from their official websites. The observations have been divided into two subsets: One is the training set with 9 observations from 2004-2012, and the other is the testing set including 3 observations from 2013 to 2015.

There are three stages in the proposed scheme. Figure 1 demonstrates the flowchart of the proposed scheme, which is briefly explained below:

Step 1: To collect relevant data. According to published research, the 17 subdivision industries growth values [3], 3 historical container throughput variables [14], 6 derived variables of historical container throughput [12] and container throughputs of top 20 container ports except the target port are collected from relevant websites and official reports.

Step 2: To calculate the CSCI based on container throughputs of top 20 container ports. After calculating the CSCI, all these data will be used to build the forecasting model.

Step 3: The forecasting container throughput will be estimated by the forecasting model.

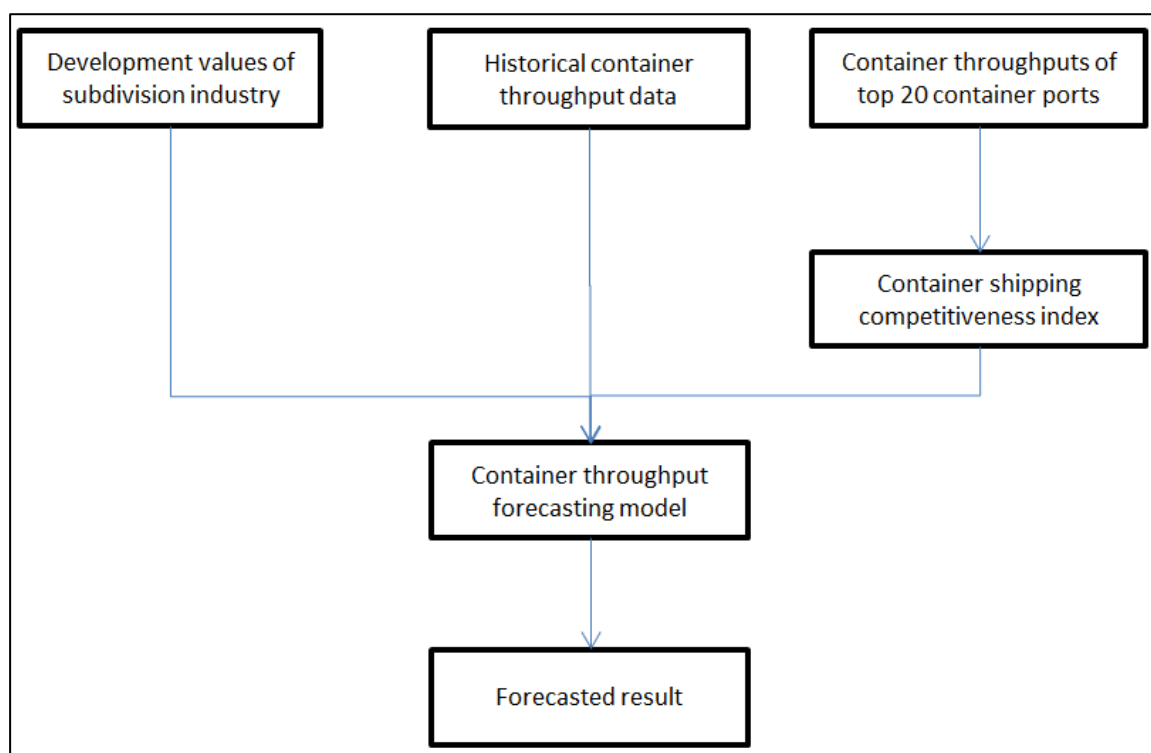


Figure 1: The flowchart of the proposed container throughput forecasting scheme



Three other forecasting models, which are ARIMA, Linear Regression (LR) and Multivariate Adaptive Regression Splines (MARS), are employed in order to benchmark the performance of the proposed scheme. Meanwhile, each model has two versions, one is with CSCI and the other is without CSCI (i.e., 3 x 2 different sets of experiments). ARIMA is an exception as it is autoregressive in nature and only historical data are related. It is not possible to include CSCI. In total, there are 7 different sets of experiments. The aim is to verify the usefulness of the proposed index. Four assessment criteria have been used to evaluate the performances of these models and the expressions of these criteria are illustrated in Equations 1 to 4. Where  $y$  is the real value of the container throughput and the  $f(x)$  is the fitted value or the forecasting value, and  $n$  is the number of data pairs,  $y$  and  $f(x)$ .

$$MAPE = \frac{1}{n} \sum_{i=1}^n \left| \frac{y}{f(x)} - 1 \right| \quad (1)$$

$$RMSPE = \sqrt{\frac{1}{n} \sum_{i=1}^n \left( \frac{y}{f(x)} - 1 \right)^2} \quad (2)$$

$$MAE = \frac{1}{n} \sum_{i=1}^n |y - f(x)| \quad (3)$$

$$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^n (y - f(x))^2} \quad (4)$$

## RESULTS AND ANALYSIS

Following the procedures of the proposed scheme outline in previous section, the forecasting model has been built and the results are presented in this section. Figure 2 demonstrates the 3 factors extracted from the container throughputs of top 20 container ports. It can be seen that factor 1 represents the ports which are able to keep their competitive power, factor 2 represents the ports that are losing their business and the ports represented by factor 3 are at steady state. Another finding is that the situation of the world container shipping industry had been changed after 2009 when the American financial crisis happened.

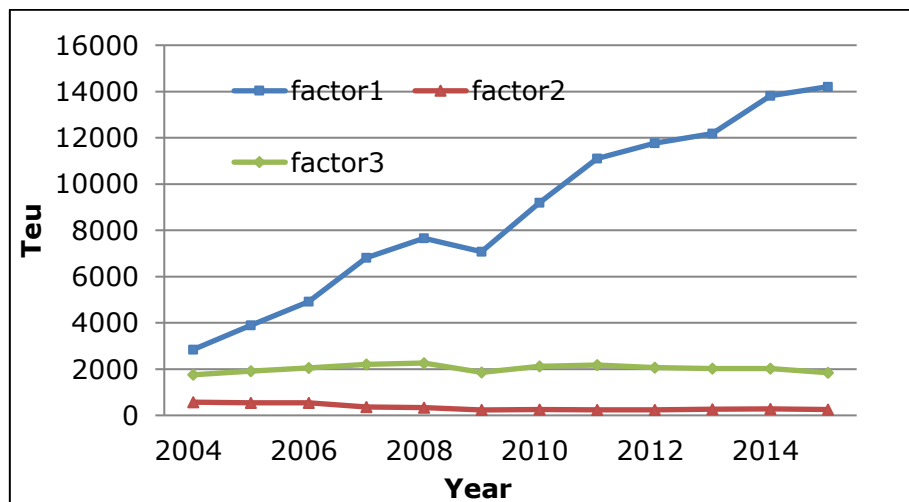


Figure 2: The three factors of the container shipping index from 2004-2014

After extracting these three factors, the aggregated CSCI can be calculated. Equation 4 demonstrates the expression of the CSCI.

$$CSCI = 0.488f_1 + 0.254f_2 + 0.109f_3 \quad (5)$$

The assessment criteria are shown in Table 3. Support Vector Regression (SVR) with CSCI outperforms other models and SVR without CSCI is in the second best. The reason is that the container throughput forecasting is not a simple linear problem, but a complex and non-linear problem. SVR is a machine learning technique which is able to capture the patterns from historical data and to identify the non-linear relationships between multiple input variables and the target variable. The linear regression models with and without CSCI are the worst two of the 7 models, which confirm that the container throughput forecasting is not really a linear problem. Because MARS is able to capture sectionalised linear patterns, the performance of MARS is better than LR. As mentioned before, ARIMA is an effective forecasting model in short-term forecasting, that is the reason why ARIMA is better than MARS and LR. By comparing the models with CSCI and models without CSCI, it can be seen that each technique with CSCI outperforms the corresponding technique without CSCI, for example, the SVR with CSCI is better than SVR without CSCI. The reason is that, the CSCI represents the external market environment of the container shipping industry, which enhance the model accuracy by taking this into consideration.

<b>Models</b>	<b>Criteria</b>			
	<b>MAE</b>	<b>RMSE</b>	<b>MAPE (%)</b>	<b>RMSPE (%)</b>
SVR with CSCI	44.14	53.05	2.33	2.74
SVR without CSCI	41.24	51.15	2.35	3.01
ARIMA	61.80	74.61	3.15	3.69
MARS with CSCI	120.73	140.43	6.23	7.01
MARS without CSCI	210.59	233.65	10.89	11.76
LR with CSCI	216.44	248.73	11.15	12.41
LR without CSCI	331.57	356.14	17.33	18.15

Table 3: The forecasting results of Ningbo Port container throughput using the SVR, MARS, LR and ARIMA

## DISCUSSIONS AND CONCLUSIONS

Good development of port is based on proper port management decision and the basis of the proper port management decision is the accurate throughput forecasting result. At the same time, containerised trade plays an important role in the maritime trade. Therefore, container throughput forecasting is important to help port managers to make correct decision. This paper proposed a container throughput forecasting scheme and a CSCI to represent the international container shipping environment. By comparing the results of 7 models, the proposed scheme is better than other models and the CSCI has its value to improve the accuracy of the forecasting result. In short, the proposed scheme is an effective container throughput forecasting approach by taking domestic socio-economic data and external market data into consideration. The paper verifies that, apart from the data sources, machine learning approach is still a better choice compared to traditional methods in terms of forecasting accuracy.

Like many studies, there are a number of limitations of this study. The scheme only considers the overall container throughput as the input data. However, there are four types of container throughput, which are full import container, empty import container, full export container and empty container. Every port has these four types of container, the volume and variation of different types of container represent different economy state, which may influence the container throughput. Therefore, to improve the forecasting model, these data should be included. Another issue is that, the development of the subdivision industries are interacted with each other, which should be considered in the future research. Finally, only SVR is considered in this paper, and other machine learning approaches should be taken into account. Eventually a customised machine learning approach tailor to this problem would be desirable.

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## **Session 6: Inventory and Warehouse Management**

# THE IMPACT OF B2C COMMERCE ON TRADITIONAL B2B WAREHOUSING

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## ABSTRACT

### PURPOSE

With the emergence of electronic commerce, traditional warehousing companies are increasingly required to offer services to clients doing B2C commerce. This challenges both existing operations and information systems as they are often designed to support more traditional B2B commerce. As a result, it is important for warehousing companies to understand the special requirements of B2C commerce in order to appropriately design and adapt their operations. In this paper we study this issue and propose a model for examining the similarities and differences between B2B and B2C warehousing.

### DESIGN

A two-stage methodology is used in this study. We first develop a theoretical model based on existing literature, to examine the similarities and differences between B2B and B2C warehousing. In the second stage, the model is used to study the impact of B2B and B2C commerce on key warehousing operations (i.e. receiving, storing, picking, shipping, other value-added services) and on supportive activities (e.g. performance evaluation, technology and equipment). In order to study this impact, data is collected using two research methods –practitioner interviews and direct observations at a case company offering both B2B and B2C offering.

### FINDINGS

This study highlights the different requirements and needs B2B and B2C commerce have in terms of warehousing services. It shows how the different nature of B2B and B2C commerce affects different elements of warehousing. It also illustrates the fact that operations and information systems designed for B2B warehousing are not always suitable for B2C.

### VALUE

Existing frameworks and tools for warehouse design and management do not recognise the differences between B2B and B2C warehousing. Moreover, the model proposed in this paper itself can be used as a tool for studying specific B2B and B2C projects and examining how existing operations have to adapt to satisfy them.

### RESEARCH IMPLICATIONS

This research study opens up a new area of investigation into how to adapt existing B2B operations and information systems to also cater for B2C customers (and the opposite). Data collection was conducted using interviews and observations, and there could be differences in different countries and industries. Future research could use a survey-based methodology to validate the model using the warehouse managers' view on the impact the type of commerce has on warehousing.

### PRACTICAL IMPLICATIONS

The results of this study indicate that even though the differences between B2B and B2C warehousing are significant, there are opportunities for effectively servicing both types of

commerce within the same warehouse. The model can be used to understand the challenges that will be faced by companies willing to offer both types of services.

## **INTRODUCTION**

The tremendous growth of e-commerce is challenging logistics operations both at the warehousing and the transportation stage (Yu, Wang, Zhong, & Huang, 2016). Increasingly, more and more end-customers prefer to place orders for goods of any kind online and have them delivered based on their special needs and requests (Kang, Moon, Kim, & Choe, 2016). At the same time, online shopping events like the "Cyber Monday" in the US and the "Singles Day" in China lead to a significant amount of orders placed in a matter of hours and fulfilled in a few days.

Besides the increase in the number of orders placed via on-line channels, due to the emergence of omni-channel retailing, orders placed via more traditional channels (e.g. physical stores) are often fulfilled in distribution centres and delivered directly to a customer's home or collection point (Hübner, Kuhn, & Wollenburg, 2016). As retailers aim to offer a seamless shopping experience to their customers, they also require the logistics services associated with that experience to be able to satisfy multiple different customer requirements (Wang, Mao, O'Kane, & Wang, 2016).

The impact of these trends on business-to-consumer warehousing is significant as the changing role of the end-customer creates new challenges for inventory management and order fulfillment (Manzini, Bozer, & Heragu, 2015). With customers placing orders at any hour with very short lead times while being flexible to change or cancel their orders after their placement, warehouses face an increasing number of disturbances (Giannikas, Lu, Robertson, & McFarlane, 2017). Moreover, logistics companies with warehouses designed for business-to-business commerce are increasingly required to offer consumer-order fulfillment services in order to extend their business offering to their clients and avoid falling behind the competition.

As a result, traditional warehouses processing orders delivered to business clients need to deal with the challenges imposed by B2C commerce. In this paper, we investigate this issue by exploring the similarities and differences of B2B and B2C warehousing. We begin with a brief review of the relevant literature and we then develop a theoretical model to be used in our comparison. The methodology used in this study is described in the section that follows. We report key findings and results before concluding this paper in the last section.

## **THEORETICAL BACKGROUND**

Warehousing has attracted a lot of attention by the academic community, especially in the last two decades. As the importance of warehouses increases in modern supply chains, the effective design, management and control of their operations has been an on-going research question (Faber, Koster, & Smidts, 2013).

Warehousing research can typically be grouped in two categories (Davarzani & Norrman, 2015; Gu, Goetschalckx, & McGinnis, 2007; Richards, 2014). The first category focuses on the planning and management of the four main warehouse operations/entities; that is, receiving, storing, picking and shipping. Using mainly mathematical modelling, simulation and case study research methods, research in this category examines ways to more effectively manage the processes associated with these four operations and to improve decision making. The picking operation is perhaps the most widely studied one, with studies focusing on batching, routing, sorting

The second category includes research associated with the supportive entities of warehousing; that is, all the necessary procedures and decisions that need to be made in order to enable a warehouse to properly operate. There are multiple different views on what constitutes a supportive entity but the list typically includes, infrastructure/

warehouse design, operations strategy, technology and equipment, performance evaluation, human resources (Gu, Goetschalckx, & McGinnis, 2010).

A review of the systems, tools and algorithms developed for warehouse management, indicates that they do not often care for differences between different types of commerce and their associated challenges. The majority of them focus on specific cases given a particular warehouse type, demand, product characteristics etc. without investigating how they should adapt to satisfy orders placed by business clients and/or end-customers. As a result, it is often hard to distinguish between tools and algorithms that are more suitable for warehousing offering B2B or B2C services. Perhaps more importantly it is hard to understand how a particular tool needs to adapt in order to still be applicable in cases where a company wishes to extend its offering to other types of commerce.

## **THEORETICAL DEVELOPMENT**

In order to examine the similarities and differences between B2B and B2C warehousing, we develop a theoretical model based on existing literature. The model consists of two main parts. The first part, demonstrates the key aspects differentiating B2B and B2C commerce from the perspective of warehousing. The second part is adapted from relevant frameworks found in warehousing literature (Gu, Goetschalckx, & McGinnis, 2007; Davarzani & Norrman, 2015) and describes the four main warehouse operations and the supportive entities.

This model will later be used to examine in more detail the similarities and differences between B2B and B2C commerce as well their impact on warehousing. In this study, we focus mainly on the warehouse operations and we comment briefly on the potential impact on the supportive entities.

### **Aspects differentiating B2B vs B2C commerce**

We identify four aspects that differentiate B2B and B2C logistics/commerce:

1. *Products*: Even though a big number of products can be ordered by end-customers today, there are certain items that are mostly used from businesses only. An extreme example could be an aircraft wheel and its associated mechanism.
2. *Orders*: Orders placed by end-customers are expected to be smaller both in terms of quantity and value. This is due to the fact that individual customers tend to satisfy their personal demand or the demand of their household although businesses often satisfy the demand of their own customers, whether these are corporate or consumers.
3. *Client*: We use the term client to refer to the organisation who is buying logistics services from the warehousing company and who is the reason for the placement of orders to a warehouse. In B2B, clients vary significantly as these can be manufacturers, distributors and wholesalers, retailers, corporations of any type or even other logistics providers. In B2C, clients are often retailers (of different sizes) who allow end-customers to place their orders via an online channel.
4. *Receiver*: In B2B commerce, the receiver is typically a company and orders are delivered to its premises. This may vary from large distribution centres to small retail stores. In B2C, the receiver of an order is an individual end-customer requesting delivery at a home or work address or a different collection point.

### **Warehouse operations**

As discussed in the previous section, there are four main warehouse operations. Here, we provide a short description of each one of them. The interested reader is referred to the relevant reviews noticed in the previous section for a more detailed analysis.

1. *Receiving*: This is interface of a warehouse for incoming goods and material flow. Products are delivered to the warehouse, unloaded at receiving areas and checked for accuracy and completeness.

2. Storing: Once products have been received by a warehouse, they need to be organised within the warehouse in order to utilise available space and support the future picking of items.
3. Picking: Picking often initiates with the receipt of customer orders. The term is used to describe all those activities required to collect the items required for the fulfilment of an order.
4. Shipping: Similarly to receiving, shipping is the interface of the warehouse with the outside world but it is responsible for outgoing shipments. Picked items are transferred to shipping docks and loaded to trucks for transportation.

### **Warehouse supportive entities**

In the previous section we saw how other decisions need to be made in order to operate a warehouse. This part of the model aims to capture these decisions and processes. We use the term “supportive entities” to refer to these using the terminology of (Davarzani & Norrman, 2015).

### **METHODOLOGY**

A two-stage methodology was used in this study. We describe each stage in more detail next.

#### **Stage 1**

At the first stage a theoretical model was developed based on existing literature. The aim of the model was to guide our data collection and analysis for the factors differentiating B2B and B2C warehousing. This model was described in detail in the previous section. We focus mainly on the warehousing operations rather than supportive entities, but we also comment on a small sub-set of supportive entities.

#### **Stage 2**

At the second stage data was collected using two different methods: interviews and direct observations.

Interviews were conducted with warehousing practitioners from six companies. The companies were selected due to the fact that they are offering both B2B and B2C warehousing services to their customers. A semi-structured questionnaire was used to guide these interviews with questions covering both the differences between B2B and B2C commerce and the impact they have on warehousing operations and other relevant activities.

A case company in China was selected for carrying out direct observations. The research team visited six warehouse bases in three different provinces of China offering B2B and/or B2C services. Warehouses offering B2C services were associated orders coming through e-commerce channels. During the visits, the team had the opportunity to observe the different ways warehouses were operated as well as have discussions with warehouse managers and staff members on the management of warehouse operations and relevant activities.

### **FINDINGS**

We report findings from analysing collectively the data gathered from interviews and direct observations. We begin with an examination of the comparison between B2B and B2C commerce from a warehousing perspective. We examine each of the four aspects of our theoretical model separately:

1. *Products*: The range of products available to end-customers increases day after day and consumers can directly order a large variety of goods they need for various aspects of their life (from repairing a car to cooking a meal). Nevertheless, certain products are only sold in a B2B context and it is likely that this will not change, at least in the near future. Warehousing companies that offer both B2B and B2C services are, however, likely to handle a similar product range



in both types of commerce. This is likely due to the way their business model has evolved; increasingly they are asked by their clients to offer both types of services for a certain product type. In cases like this, the products remain the same, however, the unit of measurement might differ. B2B often requires handling cases of items although B2C handles items at the individual level, e.g. a case of USB flash drives versus a single drive.

2. *Orders:* There is a big difference here, as B2C orders tend to be significantly smaller. Most e-commerce orders contain only 1–2 items, with perhaps the only well-known exception being grocery items. On the contrary, B2B orders are large in size and can often fill an entire truck. They also often consist of a small range of SKUs but in big quantities. Another difference has to do with demand partners. Although both types of commerce face peak periods driven by the same demand signal (end-customer orders), business orders can often increase by 3–10 times while consumer orders can increase by 100–300 times (one can take for example the Singles Day event in China). Moreover, the peak periods differ over the year, even if they are due to the same event. For example, the Christmas period creates very high levels of B2C demand in December but this is translated to high B2B demand in October/November. Finally, most B2C orders are often placed at lunchtime, in the evenings and weekends while B2B orders are placed during working hours.
3. *Client:* The client of a B2B service can vary a lot compared to the client of a B2C service. B2C clients are often retailers interested in selling over an on-line platform or wishing to extend their omni-channel offering. On the other hand, B2B clients can vary a lot. An interesting observation is that more and more manufacturers or brand owners wish to sell directly to end-customers thus moving from purely B2B sales to a hybrid model often fulfilled by the same warehousing company. B2C clients also tend to request for more services such as receipt attachment, gift wrapping etc. Finally, from a business perspective, B2B clients often book larger areas of a warehouse for long-term use in order to ensure the maximum required space availability although B2C clients book smaller spaces based on the volume they expect to sell per period. This latter issue leads warehousing providers to serve multiple B2C clients from a single warehouse at the same time.
4. *Receiver:* A typical warehouse services a much larger number of receivers, geographically dispersed in B2C compared to B2B. Moreover, the requirements of each type of receiver differ; end-customers value short lead times, order tracking information, late cancellations and amendments as well as other factors affecting the order-delivery experience. There is normally no interaction between a warehousing provider and the end-customer. In B2B, given an on-going collaboration, the receivers are relatively stable (e.g. a warehousing company will be responsible for delivering to certain retailers over a period of time). This allows a warehousing company to have a regular interaction with the receiver, collaborate with him for a longer period of time and manage disruptions more easily.

We will now examine the impact of the aforementioned differences on each of the four main warehouse operations:

1. *Receiving:* Incoming inventory arrives in bulk in both types of warehousing. However, the complexity in B2C incoming deliveries might be higher, thus requiring more time and resource. This is due to a number of reasons. Firstly, the large number of clients per warehouse in B2C often leads to more deliveries as each one of them replenishes inventory separately and in smaller quantities. Secondly, B2C pallets are more often mixed pallets carrying more than one SKUs, thus requiring more time to unload and check. Thirdly, as some B2C clients can be small retailers, they might not care for loading a delivery truck with their goods in a tidy way that will allow easy and fast unloading.

2. *Storing*: In B2B, a warehouse provider receives, and therefore needs to store, large quantities of the same SKU. Especially in cases when pallets contain a single SKU, this allows for easier storing as pallets can be moved from a truck directly to a storage location without extra handling. It is therefore common for storage locations to store pallets carrying a single SKU. On the contrary, storage locations in B2C are often used to store more than one SKUs, either as individual items or in boxes and containers. Especially when small items are stored in a B2C warehouse, the number of SKUs per storage location can be particularly high. It is also critical that items are stored in a way that human pickers can later pick them easily and without the need of extra equipment such as ladders and forklifts. Moreover, B2C warehouses often require a storage location assignment process that meets demand patterns (e.g. differentiate between slow and fast-moving areas) in order to minimise travel time during picking. In B2B, on the other hand, storing aims to mainly improve space utilisation and avoid less-than-full storage locations. Finally, due to the small quantities stored from each retailer in a B2C warehouse, turnover is much higher than in B2B warehouses thus making storing to happen more frequently.
3. *Picking*: The main difference here is the unit of picking due to the difference in orders placed; whole pallets are normally picked in B2B while individual items are picked in B2C. This requires different material handling equipment in each case. Also, as B2B orders are normally large in size, orders are picked in sequence, having multiple staff members picking the required items at the same time. As B2C orders are much smaller, multiple orders (perhaps placed for items of different retailers) are grouped and picked together in a single pick tour. A key challenge here is when a provider has to manage orders of different priorities from the same warehouse (e.g. Amazon Prime orders vs regular orders). Similarly to storing, picking in B2B aims to primarily optimise space utilisation while B2C focuses more on reducing order preparation times. This is the reason why batching and route optimisation are much more important in B2C. Finally, B2C picking is likely to require time for sorting and order consolidation, especially when the contents of an order are picked by different pickers (and in certain cases different buildings).
4. *Shipping*: There are many differences that impact shipping operations. Firstly, the transportation provider differs. In B2B, carriers and truck companies offer transportation services, which is often organised at an order-basis, depending on the characteristics of the specific order. In B2C courier, express and parcel companies (CEP) often last-mile logistics services to end-customers. These often visit the warehouse a few times a day to pick up parcels. This impacts the time available for picking as well as when an order should be picked by. Secondly, It is common for each warehouse to collaborate with more than one CEP companies as clients and end-customers can have different requirements. If this choice is given to the customer during order placement, sorting for shipping can also be time consuming. Thirdly, the loading process needs to be managed differently as pallets are shipped in B2B while parcels of multiple sizes are shipped in B2C. Finally,

An interesting factor that we observed while studying of the above operations is the increasing importance of value-added services in warehouses (Richards, 2014). These refer to activities that can be performed within a warehouse and offer extra services to a provider's clients. Our discussions and observations revealed that these services have become an important part of warehousing and need to be properly managed along with the four more "traditional" operations discussed earlier. In certain cases, they change the meaning of traditional operations. For example, B2C picking almost always requires product packing, receipt attachment and labelling. The impact of these value-added services can be so important that can affect the role of a warehouse itself as it can be

seen as a part of the supply chain with cheaper labour (compared to stores) that can be used to further process a product.

Examples of value-added services observed in this study include the following. In B2B, pre-retailing services to make handling at next stage in supply chain (e.g. stores) easier, labelling, RFID attachment, change of manuals, power cords and software language (for electronics). In B2C, gift-wrapping, leaflets/coupons attachment, returns management, special packaging, ironing and washing.

With regard to the supportive entities, we make the following short comments on three areas:

- *Equipment and IT*: Due to the differences in handling units, different equipment needs to be used for picking items in B2B and B2C. In the former case, forklifts or similar equipment are being used to pick and carry pallets although in the latter, trolleys or parts-to-picker systems are more suitable. Warehouse management systems are necessary in both cases but need to be more flexible and adaptable to meet changes in demand and client requirements in B2C.
- *Human resources management*: safety is a critical issue regardless of the type of commerce. This is why having both people and vehicles working together in the same workspace can be hard. Moreover, due to the need to handle special equipment in B2B, finding skilled employers staff can be more challenging (e.g. forklift drivers or staff that can carry heavy items).
- *Performance measurement*: The basic principles for managing performance apply regardless of commerce type. These are mainly storage density/space utilisation and minimum travel distance. However, B2B warehouses tend to focus more on the former along with high levels of accuracy and successful on-going collaboration with receivers. On the other hand, B2C warehouses prioritise the outbound processes, speed and minimising handling costs

## CONCLUSIONS AND DISCUSSION

In this paper, we proposed a theoretical model for identifying similarities and differences between B2B and B2C commerce and understanding their impact on warehousing. The model was used in interviews and direct observations to identify and analyse some of the key factors of B2C affecting traditional warehousing. The results of this study can be used by warehouse providers wishing to extend their business offering to satisfy different types of clients. The model itself can be used for further examining specific cases in more detail.

We conclude this paper with three points of discussion that can lead to future areas of research.

Firstly, due to the popularity of special promotion/shopping days, B2C warehousing can use practices from B2B warehousing to satisfy the challenges emerging from very high demand. As an example, the picking operation can be altered to allow a whole pallet to be picked when a promotion item is ordered by several different customers on a single day. Moreover, items that will be on sale can be pre-processed to save valuable time, e.g. items can be packaged before an actual order is received and stored until they can be labelled accordingly.

Secondly, as business clients and receivers are trying to better manage holding inventory, smaller orders with higher variety and shorter lead times might soon become a norm in B2B. As a result, B2C practices might be useful to handle orders with different characteristics than traditional B2B orders. One could imagine separate pick lists to be created by the warehouse management system when items can be grouped together and be picked in a single pick tour due to orders with small quantities and large variations.

Lastly, and perhaps more importantly, there is a big opportunity for merging and co-managing B2B and B2C operations and inventory. As many warehousing providers serve both types of commerce from their premises –often assigning different areas of a warehouse to different types of clients– the benefits from merging them can be significant. For example, common inventory can better be managed as it can be shared and used according to actual demand. Secondly, staff can be quickly re-allocated during the day at places where manpower is needed most as workload differs between B2B and B2C during the day. Finally, available space in a warehouse can be better utilised according to the actual items needed to be stored rather than according to pre-allocated zones and buildings.

## **ACKNOWLEDGMENTS**

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# USING MILK RUN TO DEAL WITH UNCERTAINTY IN DEMAND IN A CAR ASSEMBLER

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## Abstract

This work presents a collaboration process between university and a company to solve a specific problem using geographic information systems and logistics modelling process applied to transportation. Car assembler companies in the periphery of Europe have an additional challenge when building their attractiveness in the scope of the economic groups they belong to as longer distances to receive their supplies involve additional costs. Adding to this challenge, the economic crisis brought a new scenario of uncertainty in demand, which is translated into additional inventory costs. In order to deal with these additional costs as well as to reduce transportation costs, the purpose of this research was to develop a logistics model, based on custom made software that allows generating transportation runs that was able to reduce inventory and transportation costs without sacrificing service quality for the analysed car assembler company.

## INTRODUCTION

Milk run logistics relates to a route in which products are moved from a point of origin to multiple points of destination or from several points of origin to multiple destinations (Chopra and Meindl, 2007). It is specially fitted to situations with points of origin close to each other (Arvidsson, 2013). This routing strategy leads to reduction in transportation costs and improves vehicle space utilization (Chopra and Meindl, 2007). The gain in this concept is to increase supply frequency without increasing freight costs and decreasing the inventory costs in material and containers as well as warehouse space. This is achieved with the following strategy: The goods are not supplied from each supplier to the customer on radiating individual tours but each truck coming from suppliers who are involved in Milk Run collects part of the materials in a closed "traffic circle".

The benefits resulting from Milk Run are: 1) Same freight costs despite increased delivery frequency and smaller partial deliveries; 2) Better visibility of inventory; 3) Improved supplier communication; 4) Reduced stock in warehouse and thus reduced handling expenses; and 5) Increased inventory turnover for full and empty packages (Piontek, 2009).

Volkswagen Autoeuropa (AE), a car assembler plant located in Portugal, wants to implement this concept to achieve savings but due to its dynamic production demand it is a risk to use this concept. To overcome this problem, this paper aims at analysing inbound logistics flows and identifying solutions for possible suppliers to join a new milk run delivery system using geographic developed software. This software is based on demand and tries to fit milk run routes based on production data and pre-defined criterion from AE.

The most important operational decision related to transportation in the supply chain is a dynamic orders environment, where pre-defined transportation plans could be changed. Typical objectives when routing and scheduling vehicles are a combination of minimizing cost by decreasing the number of vehicles needed, the total distance travelled by vehicles, as well as eliminating service failures such as a delay in shipments. Also a daily deliveries is an important goal to achieve. The proposed model structure takes into account:

- Vehicle Routing Problem (By Vogel's Approximation Method) and Traveling Salesman Problem (Lahyani et al., 2015);
- Capacitated Transshipment Problem (Ozdemir et al., 2013);
- Main variables; 1) Ct = Cost per trip; 2) L = Distance covered by a vehicle for a milk run; 3) K1 = Minimum fixed transportation cost for a vehicle; 4) K2 = Transportation cost per kilometre; 4) K3 = Loading cost at each vendor; 5) N = Number of suppliers in a milk run; 6) Only one type of truck (limited by 24T or around 100m<sup>3</sup>) is considered as mode of transport; and 7) Loading and unloading time and cost is assumed to be constant for all cases.

## CASE STUDY DESCRIPTION

This section is based on information provided by the logistics department of AE where the systematization process was performed. All the suppliers of the components of AE receive the respective orders of parts by EDI (Electronic Data Interchange), as illustrated on Figure 1. The electronic exchange of data between suppliers and AE is made in real time and two types of messages are made available from the internal proprietary system from Volkswagen: FAB - weekly requests with forecast of 6 months and LAB - daily requests with maximum horizon of 10 days. The EDI systems, besides reducing the cycle of request/supply, allow decreasing costs and operational mistakes, fundamental optimizations in a Just in Time organization. The expected results are low inventories, situation in which AE is Best-in-class in the Volkswagen group. AE applies the simple principle of replacing stock with information. The supply chain department parameterizes in the VW system, the defined transit time for each supplier. Depending on the country of origin it can vary from 1 to 12 days. The frequency to collect reused packing's (Inverse Logistics: once a month, weekly, daily) is also agreed.

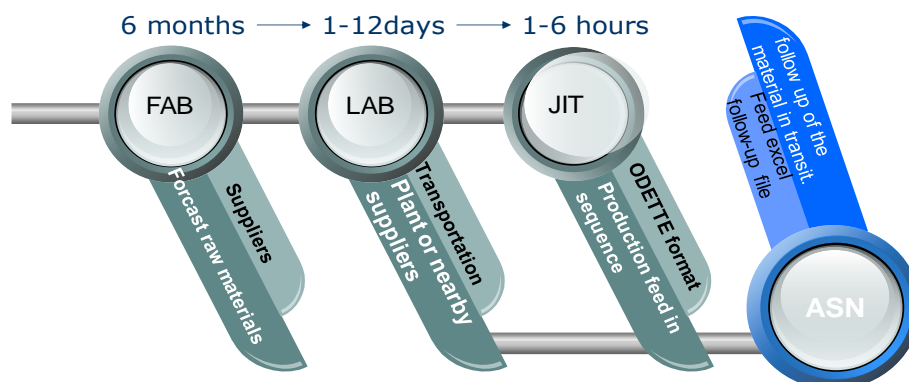


Figure 1 – High level vision of Electronic Data Interchange implemented at Volkswagen.

## Transportation Characterization

In order to characterize transportation the following information was required: price of the parts, volume, weight, daily volume and readiness of containers. The analysis of this data allowed configuring the optimized number of weekly deliveries. It will serve as the basis to the weekly requests to the suppliers. When receiving the requests, each supplier has the responsibility of requesting, until the 12h day prior to delivery, to the pre-defined transport company that collects in its region, the needed space to transport its volume, making information available about the number of unit loads, weight and volumes. Two types of collects are possible:

- The chosen transportation collects and direct sending to AE.
- Use of Cross-Docking (consolidation) centres from where, on a daily basis, direct trucks exclusively dedicated to this operation leave to AE.

After the transporter collects the volume, the supplier should issue an ASN (Advance Shipping Notice) by EDI, which is integrated in the AE supply chain systems. This allows the Supply Chain analyst to follow up of the material in transit. When a truck arrives at AE it goes to the main gate to proceed to the verification and registration.





1. Fixation of weight and volume of suppliers in a particular region. In the AE case data was extracted from an excel file with orders' data;
2. Selection of potential Milk Run Suppliers route and delivery frequency fulfilling maximum volume availability and weight legal limits;
3. Selection of Milk Run Suppliers based on the Milk Run potential savings;
4. Definition of Milk Run Parameters: limit of weight and volume, time windows, delivery frequency and maximum number of Milk Run Suppliers;
5. Development and evaluation of Milk Run Alternatives;
6. Specification of the Milk Runs with respect to the fourth point under these parameters, plus the necessary contingency plans;
7. Implementation of the Milk Runs: definition of a Milk Run Schedule, conduct supplier workshops, testing and Milk Run Controlling.

The main problems identified were:

1. Excel data extraction is complex;
2. Diversity of rules and restrictions to implement.

### Special Racks supplier location Cluster identification

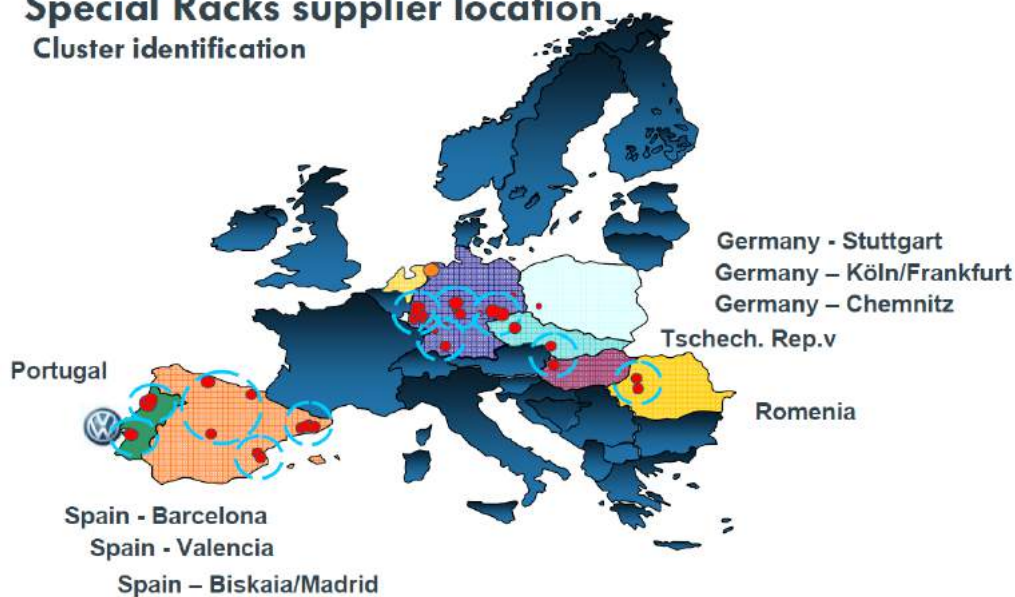


Figure 3 - Output of a geo-reference process of AE suppliers based on Google Maps API.

An informatics tool was developed to support AE based on the requisites defined above to define the milk runs. Milk runs are preferable on a daily basis (save storage space, transportation and racks) than the route optimization or even the reduction of the number of truck runs (AE works in JIT and this is a requisite from logistics department). The most important data is the precision schedules to work in a low stock basis. For this problem we looked first into suppliers' daily volumes to identify the most important ones (largest volume). Suppliers with a daily volume above 10Ton or 40m<sup>3</sup> were identified; nearby suppliers (distance under 150Km -configurable parameter) were associated to this anchor supplier.

If the number of nearby suppliers was bigger than 5, different runs were attempted. The number 5 is a request by AE because it limits the transit time costs and creates uncertainty. If the number of supplier stops increase, the probability of losing the pre-defined slot for loading at the supplier also increases. This could cause serious delays in a transportation operation in which time is the most important asset.

In the created process the weight and volume of each part is an important parameter and we find that most of times the correspondent VW information system does not have the information, because Germany Engineer does not fill this field. To solve this problem we extract this missing information from transportation invoices using the process identified in Table 1. The transportation data extraction is complex due the fact several transportation companies can be involved in the same transportation process, at different stages and

each of them creates an invoice. For example, the same material can have up to three registers (see Table 1) on that database, which would formally correspond to three different transportations in the supply flow, e.g. 1) from the supplier to a consolidator centre; 2) from consolidator centre A to consolidator B; 3) from the consolidation centre to AE (see example on Table 1). In the added squares on duplicated data correspond to different trucks used at different stages in the transportation process. From the transportation database, part numbers weight and volume with associated supplier were identified and this was introduced in a database.

Table 1 – Process of extraction parts weight and volume from transportation invoices.

Transportation Invoice		Extract Information		Identification of double or triple entrance		Transportation Data		Supplier address, volume and weight	
Zip Code	City	Weight	Volume	Volume with Rack	Arrive Date				
42553	velbert	0,31	191	191	22-01-2011 16:16	}	Double Entrance two transportation used		
42553	velbert	0,31	191	191	22-01-2011 16:16				
42551	Velbert	0,421	78	105,25	22-01-2011 16:16				
42551	Velbert	0,335	55	83,75	22-01-2011 16:16				
42551	Velbert	0,421	69	105,25	22-01-2011 16:16				
42551	Velbert	0,426	109	109	22-01-2011 16:16	}	Triple Entrance three transportation used		
42551	Velbert	0,426	109	109	22-01-2011 16:16				
42551	Velbert	0,426	109	109	22-01-2011 16:16				
42551	Velbert	0,426	109	109	22-01-2011 16:16				
42553	Velbert	1,707	417	426,75	22-01-2011 16:16				
		3,62	919	1021					

## APPLIED METHODOLOGY AND MAIN RESULTS

In this section, the main results using 5-week data are presented. First, the main suppliers are identified on a volume basis (more than 10 Tons in a week). Nearby suppliers will be clustered and from this process the possible runs are identified. We show 3 cases were performed and only one is shown in this paper. Additionally, this type of proposal should be complemented by a decision support system that can react to changes (flexibility) on pre-defined actions. Maximum truckload will be limited to 90% for security reasons (last minute situations may occur).

For Milk Run Proposal 1, see Figure 4 (A) – Johann Borgers/ISE. The first milk run analysed has 2 suppliers (7 part numbers) – Johann Borgers and ISE. The current situation consists of collecting 6 types of raw materials (6 part numbers) twice a week at Johann Borgers (inbound transportation) and empty containers were sent back once a week (outbound transportation). The inbound transportation from ISE to AE occurs four times a week and the outbound is three times a week (from AE to ISE); a single part number (raw-material) is collected. Average monthly weight is 79 and 49 Tons, respectively. Data analyses of 6 months shows: 1) Johann Borgers week average of 18 Tons; 2) ISE week average of 11 Tons. The restriction to this circuit is the volume as shown by the total values to the suppliers per month: 807 m<sup>3</sup> and 109 m<sup>3</sup>. Data analyses of 6 months shows: 1) Johann Borgers weekly average of 183,41 m<sup>3</sup>; 2) ISE weekly average of 24,77 m<sup>3</sup>. Considering the purpose of this project and data available 3 different milk runs were considered. As a consequence: 1) Collect the information about current transportation (total/week); 2) Based on standard trucks dimensions define the number of required trucks per week. Table 2 shows the added weight and dimensions to the milk run. Afterwards, based on standard dimension/weight to 2 types of trucks (blue table) we define the number of trucks required to satisfy the transportation. The restriction in this case is the volume (m<sup>3</sup>). The chosen solution uses TIR truck type because it is less expensive than the Mega ones. The truckload

of this milk run is only 77%, on average, so it might be possible to add more suppliers (low frequency suppliers) to optimize transportation.

It should be noted that calculations should be done considering 90% of truckload due to need of flexibility to accommodate dynamic schedules. When running our geo-reference approach in a radius of 150km we have identified further suppliers (due to confidentiality reasons their names are not identified, only the city name) with lower cadence. Milk Run 1 (see Figure 4 (B)) starts at 6 a.m. at Supplier A (loading time is 30 minutes) and driving time to supplier B is 2 hours. At 9 a.m. the truck is ready to collect at other suppliers. These suppliers require around 69 m<sup>3</sup> and 9.7 Ton per run (on average). In this region we can put together the following suppliers (Figure 4-left): (C) 42551 Velbert; (D) 42287 Wuppertal; (E) 42899 Remscheid; (F) 40724 Hilden; (G) 41324 Mettmann; (H) 40699 Erkrath; and (I) 41468 Neuss. Since AE wants a run for 3 or 4 days per week our proposal is to create 3 different milk runs, always with these 2 main supplier added with more 1 to 3 suppliers in the same run (restriction of max 5 supplier per milk run).

The second milk run analysed has 2 suppliers (5 part numbers) – Bosh and Meritor, see Figure 5. The current situation consists in collecting raw material from each supplier independently. Once a week collect at Arvin Meritor and one transport per week of empty containers (outbound) from AE back to the supplier. There are 3 inbound runs with Bosh. The problem associated with this situation is the volume of raw-material and empty containers in stock that occupies too much space. The improvement procedure used the same steps as in Milk Run Proposal 1 (see Figure 5). The restriction is again the volume. In this situation 4 TIR or 3 MEGA trucks are needed. The decision will be based on truckload. This situation is different from the first one and there is no nearby supplier with lower frequency.

Table 2: Transportation Volume and Dimension for the identified cluster 1

Milk Run	Supplier	Total/month			Total/week			Total		Truck Traits		
		n/Parts	Volume	Weight	n/Parts	Volume	Weight	Dimension	Weight	Dimension	TIR	Mega
1	Johann Borgers	6	807	79	6	183,41	17,95	208,18	29,09	Dimension	90	103,53
1	ISE	1	109	49	1	24,77	11,14				24	24

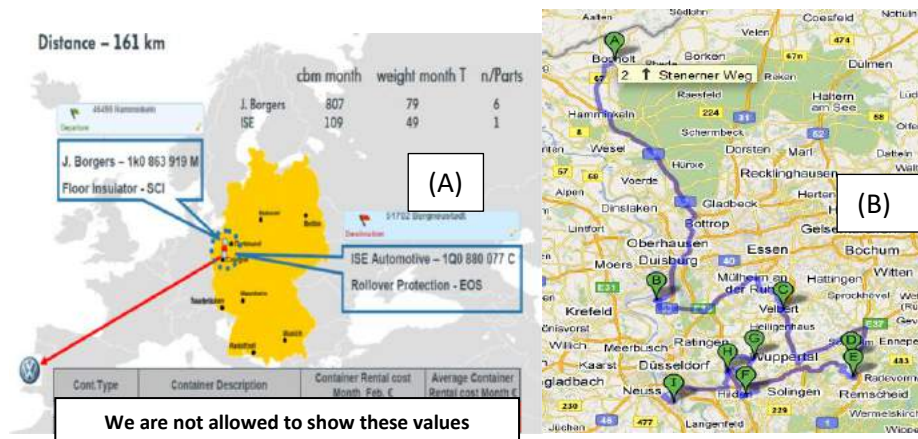


Figure 4 – Cluster 1 supplier main data, case (A) with two main suppliers, ISE and J.Brogers and case (B) smaller volume and more suppliers in the milk run

MEGA trucks could be a problem because truckload averages 94%. Therefore, following the definitions of AE, the recommendation is 4 TIR per week with 82% of truck load. Consequently, in this case there are four inbound runs a week (Monday, Tuesday, Wednesday and Friday) and one outbound per week.

Milk Run Proposal III – Takata/Oris/ETM, see Figure 6. This proposal involves 3 main suppliers in Germany. Weekly values for these suppliers are: 1) Takata: weight is 16 Tons with a variance of 6 Tons. Volume is around 81 m<sup>3</sup> with a variance of 20 m<sup>3</sup>; 2) Oris: weight is 20 Tons with a variance of 5 Tons. Volume is around 67 m<sup>3</sup> with a variance of 13 m<sup>3</sup>; 3) ETM: weight of 8 Tons with a variance of 3 Tons. Total volume is around 77 m<sup>3</sup> with a variance of 15 m<sup>3</sup>. The first proposal is for 3 trucks per week (Monday, Tuesday and

Thursday) from these 3 suppliers. As the restriction is again volume, the required volume is for 3 TIR or 2 MEGA per week, see Table 3. Based on truckload and on the restriction of 90% of truckload, this milk run should work 3 times per week using TIR truck type and achieving 75% of truckload. Now it is needed to analyse the nearby suppliers with lower frequency. The proposed solution to collect from these 12 suppliers involves one more truck than initially planned. It does not exceed 5 suppliers per milk run and not the 90% of truck load required by AE. This way milk run should work 4 days per week: 1) Run 1 (Monday) additional stops at Roedental and Salach, additional 9,1 m<sup>3</sup> available. Milk run is about 5 hours with 2 hours for loading; 2) Run 2 (Tuesday) no loading at ETM (only supplies 3 times per week). And it also collects at 3 small suppliers, Koenigsberg, Suhl and Bohmenkiruch, achieving a total of 69% of truck load; 3) Run 3 (Wednesday) the 3 initial suppliers should be collected from and also 2 additional ones, Mellrichstadt and Erlenbach. Using a TIR truck the truckload will be 77%; 4) Run 4 (Friday) is equal to Run 3 but the 2 additional suppliers are Schweinfurt and Ditzingen, achieving 87% of truckload.

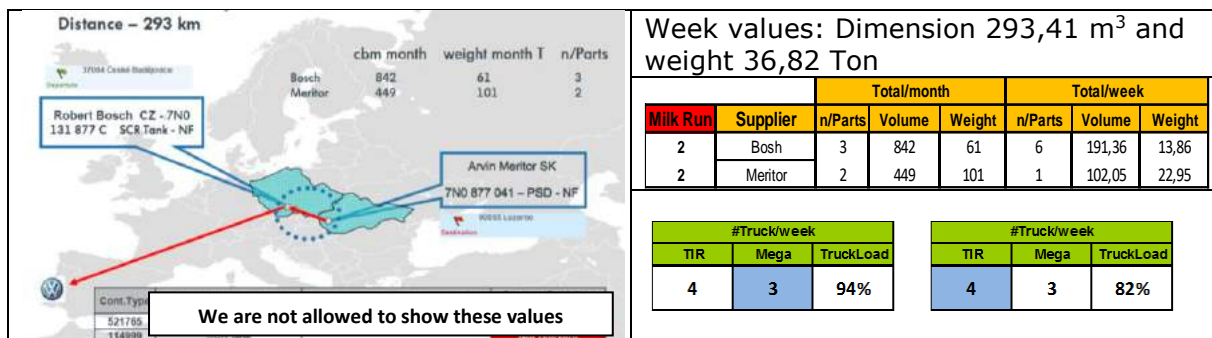


Figure 5: Milk Run proposal 2 - Transportation Volume and Number of Trucks required

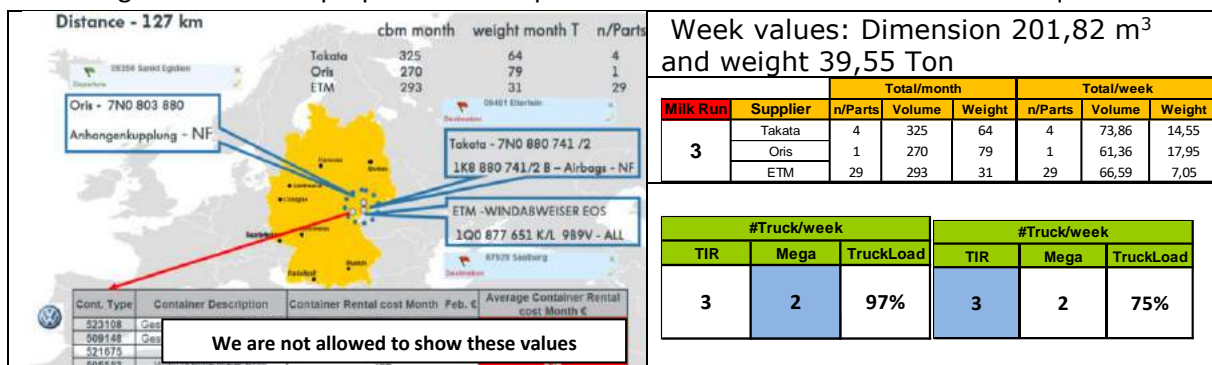


Figure 6: Milk Run proposal 3 - Transportation Volume and Number of Trucks required

Table 3: Milk Run proposal 3, with additional suppliers in 4 runs per week.

Milk Run	Supplier	Total/week			Run 1	Run 2	Run 3	Run 4
		n/Parts	Volume	Weight				
3	Takata	4	73,86	14,55	18,5	18,5	18,5	18,5
	Oris	1	61,36	17,95	15,34	15,34	15,34	15,34
	ETM	29	66,59	7,05	22,2		22,2	22,2
Suppliers	Roedental	-	4,6	1,165	4,6			
	Salach	-	4,5	1,148	4,5			
	Koenigsberg	-	6,8	1,693		6,8		
	Suhl	-	1,2	0,308		1,2		
	Bohmenkirch	-	20,3	5,067		20,3		
	Mellrichstadt	-	3,4	0,856			3,4	
	Erlenbach	-	9,66	2,512			9,66	
	Schweinfurt	-	0,8	0,195				0,8
	Ditzingen	-	21,747	4,793				21,747
	Total (Ton)				65,14	62,14	69,1	78,587
#Suppliers					5	5	5	5
Type of Truck					TIR			
Truck Load					72%	69%	77%	87%

## CONCLUSIONS



This paper introduces a milk run approach in a dynamic order environment and demonstrates its viability under these conditions, maintaining service levels while reducing transportation and inventory costs. Data from a car assembler in Portugal was used and the full information of transportation and production demand activity was considered. A software tool was developed to implement a dynamic milk run in a real scenario with support of geographic information manipulation of information with uncertainty. The developed model was able to reduce the weekly number of trips by 5 to 9% (see Table 4 with results for this case: three round trips per week, about 150 round trips per year, as well as the average distance covered per week). By reducing transit time and allowing a more often placement of orders, inventory rotation increased and inventory holding costs are lower. Due to the level of uncertainty in demand, the model also impacted positively in terms of flexibility in production scheduling. While developing the logistics software that underlays this model, nearby suppliers were clustered and a maximum load factor of 90% was considered. Two transshipment platforms were located in Germany (already existed, no cost associated). Three different milk run scenarios were developed and compared. Table 4 shows the main results with the introduction of three milk runs that are adjusted based on production demanded. This implementation allows savings on: 1) container rental; 2) transportation, 3) warehouse space and 4) inventory value. This gives an saving of 200K€/year that gives more less 1,5€/car.

Table 4 – Results of current milk run study proposal implemented in 2012

#### 1. Milk Run Proposal – Johan Borgers/ISE

Previous Situation of both suppliers: 6 truck inbound and 4 outbound



	Inbound week	Outbound week
Johann Borgers	2 x	1 x
ISE	4 x	3 x

New - 4 X Week Round trip

#### 2. Milk Run Proposal – Arvin Meritor SK/Robert Bosch CZ

Previous Situation of both suppliers: 4 truck inbound and 1 outbound



	Inbound week	Outbound week
Arvin Meritor	1 x	1 x
Bosch	3 x	-

New - 3 X Week inbound  
(Outbound Meritor 1 x week)

#### 3. Milk Run Proposal – Takata/Oris/ETM

Previous Situation of both suppliers: 11 truck inbound and 7 outbound



	Inbound week	Outbound week
Takata	3 x	2 x
ETM	3 x	2 x
Oris	5 x	3 x

New - 4 X Week Round trip

It was not possible to access information concerning information about windows time to load. Therefore some overlapping conflicting time windows may occur at some suppliers when AE tries to implement this new configuration of collect. Another possible problem is related with returnable packaging between customer and suppliers (empty containers in outbound). In terms of the value added by this project, milk runs are often used in stable environments. The results of this research lead the company to adopt milk run in their transportation options. By experiencing considerable savings the company reinforced its competitive position inside the economic group it belongs to and strengthened its economic viability. The results presented in section 4, presents a solution for a specific production environment, others can be easily adapted and created based on the current solution.

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# **A METAHEURISTIC APPROACH TO SOLVING A MULTIPRODUCT EOQ-BASED INVENTORY PROBLEM WITH STORAGE SPACE CONSTRAINTS (CASE OF INCREASED NUMBER OF PRODUCTS)**

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**Abstract:** The objective of this paper is to model a static time-continuous multiproduct economic order quantity (EOQ) based inventory management problem with storage space constraints, as a combinatorial optimization problem in the corresponding dynamic discrete time system control process for ordering increased number of products  $m=102$  products. This paper is extension of previous research paper described and published in order to investigate the behaviour of the special heuristics and VNS algorithm, and compare their efficiency, they were preliminarily tested on a hypothetical dynamic discrete time system control process (named DTSC problem) with  $m=21$  products, where the inventory management process is considered during period  $T=1$  year which is divided into  $n=365$  days and the total available storage space is equal to  $G=1400$  m<sup>2</sup>. The described inventory management problem with storage space constraints represents a widely applicable and popular problem in practice. To solve this model we have developed special heuristics based on the local search technique and a metaheuristics technique based on variable neighborhood search principle, and we have preliminary examined their efficiency and compared them with several numerical experiments. Special heuristics was developed in order to facilitate definition of number of orders and metaheuristic technique based on variable neighborhood search was developed in order to compare its results with the results of special heuristics. As the result of the study, we were able to present here special heuristics that generates a feasible set of ordering scenarios.

**Keywords:** multiproduct EOQ inventory problem, discrete time system control, special heuristics, variable neighborhood search.

## **1. INTRODUCTION**

The Economic order quantity (EOQ) model belongs to a class of classical inventory models with a known total deterministic product demand, where the order product quantity should be determined to minimize the total costs of the production, ordering and inventory holding. The model was originally developed by Harris (1915), though Wilson (1934) is credited for his early in-depth analysis of the model. It was a time without easily affordable computers and simple useful mathematical models were preferred (see Erlencotter 1989 for the history of EOQ). As we can see in Axsäter (2006), Russell and Taylor (2006), Vollmann et al. (2005), Chase and Aquilano (2004), Barlow (2003), Muller (2003), Wild (2002), even new books dealing with inventory control describe the classical EOQ model and its variants as a starting point for further understanding of inventory dynamics.

A discrete time system control is a more natural manner to describe inventory dynamics, as it is stated in Kostic (2009). A model of discrete system control could be both a simulation model of inventory dynamics and an optimization model which can give the optimal control according to a defined performance criterion.

There are numerous articles using the discrete time system control in a dynamic deterministic inventory problem. Most of them address lot-sizing problems, beginning with Wagner (1958) and Scarf (1959). In order to find an optimal inventory control for various variants of dynamic lot-sizing problems, dynamic programming algorithms are applied

(Bertsekas 1987). Numerous special heuristics and metaheuristic-based algorithms are used to solve such problems (see Zoller 1988, Jans and Degraeve 2007 for an overview).

This paper presents a static time-continuous multiproduct EOQ-based inventory problem with storage space constraints. In order to solve it approximately the problem is modeled in Section 2 as a combinatorial optimization problem in a dynamic discrete time system control process for inventory management, by defining basic elements of a discrete controlled object, according to Kostic (2001). To solve this model we have developed a special heuristics based on the local search principle in Section 3.

Section 4 contains a comparative review of numerical results obtained by special heuristics and metaheuristic technique based on VNS.

## 2. MATHEMATICAL MODELLING

We consider a time-continuous multiproduct EOQ-based inventory problem which has most of the characteristics of a well-known classical economic lot-size model.

A number of products  $m$  are given and for each product  $i$ ,  $i=1,...,m$ , the total deterministic demand  $D_i$  which should be satisfied within a finite time horizon  $T$  in the following way:

- the same amount  $Q_i$  of product  $i$  is ordered  $u_i$  times with the constant time  $t_i$  between two orderings;
- the whole ordered amount  $Q_i$  arrives on the stock simultaneously and immediately when desired, while it is withdrawn from the stock continuously by the constant rate equal to  $D_i/T$ . Shortages of the product on the stock are not permitted.

For each product  $i$  the only cost to be considered is the cost related to ordering – the setup cost  $S_i$  and the purchase cost of  $C_i$  per product unit, and the inventory holding cost of  $H_i$  per product unit in time unit. The total inventory holding cost in period  $t_i$  is calculated with respect to the average inventory level  $Q_i/2$ .

Ordered amounts of different products share the same storage with the total available space  $G$  which is known in advance, and consequently, for each product  $i$  the storage space  $P_i$ , occupied by its unit, is given. Therefore, inventory levels during the observed time period  $[0, T]$  should satisfy the following *storage space constraints*: at any moment in this period the total space occupied by the stored amount of all products should not exceed the space limit  $G$ .

According to the classical EOQ model, the total cost  $TC$  for already described inventory system is equal to

$$TC = \sum_{i=1}^m (S_i + C_i Q_i + H_i \frac{Q_i}{2} t_i) u_i \quad (1)$$

Taking into account that  $u_i = D_i / Q_i$  and  $t_i = T / u_i = T Q_i / D_i$ , the total cost  $TC$  can have the form

$$TC = \sum_{i=1}^m S_i \frac{D_i}{Q_i} + \sum_{i=1}^m C_i D_i + \sum_{i=1}^m H_i \frac{Q_i}{2} T \quad (2)$$

Then, the following inventory problem is considered: find amounts  $Q_i$ ,  $i=1,...,m$ , which satisfy storage space constraints and minimize the total cost (2).

In order to solve it approximately, the problem is modelled as a combinatorial optimization problem of the corresponding discrete time system control process in the following way.

Instead of continuous time period for ordering products, the whole time period  $[0, T]$  is divided into  $n$  periods  $t$  with the same length  $T/n$ , where  $t=1, \dots, n$ . (For example, if  $T$  is a year then  $t$  could be a day). We assume that the ordering of any product can be realised only at the beginning of a period  $t$ . As during this period of length  $T/n$  the product is withdrawn from the stock continuously by the constant rate  $D_i/T$ , then the product demand which should be satisfied within the period is equal to  $D_i/n$ ,

Instead of  $Q_i, i=1, \dots, m$ , we consider  $u_i \in \{1, 2, \dots, n\}, i=1, 2, \dots, m$ , as decision variables, while  $Q_i = D_i/u_i$ .

Now, for each product  $i$  a change of its inventory level during the whole time period can be formally represented as a discrete time system control process with the following elements:

$X_t^i, t=1, 2, \dots, n$  – the total amount of product  $i$  remaining on the stock at the end of period  $t$ .

$Y_t^i, t=1, 2, \dots, n$  – the amount of product  $i$  ordered at the beginning of period  $t$ .

If we consider  $X_t^i$  as the *state* of a process at period  $t$  then the *state equations* which describe the behaviour of the process can be defined as

$$\begin{aligned} X_0^i &= 0 \\ (3) \quad X_t^i &= X_{t-1}^i + Y_t^i - D_i/n, \quad t=1, 2, \dots, n. \end{aligned}$$

(4)

Obviously, ordering of amount  $Q_i = D_i/u_i$  is realised at the beginning of a period  $t$  only in the case when the stored amount of a product  $i$  remaining at the end of the previous period  $t-1$  is not enough to satisfy demand  $D_i/n$  within period  $t$ . Therefore, the value of  $Y_t^i$  depends on  $u_i$  and can be formally expressed as

$$Y_t^i = \begin{cases} D_i/u_i, & X_{t-1}^i < D_i/n \\ 0, & \text{otherwise} \end{cases} \quad t=1, 2, \dots, n.$$

(5)

Also, as  $X_0^i = 0$  then, consequently,  $X_n^i = 0$ .

Let us mention that the process described by (3) - (5) does not represent a typical discrete time system control process, where at each period the current state is dependent on both the previous state and a chosen value of one or several control variables. Namely, using expressions (3), (4) and (5), for a fixed  $u_i$  amounts  $X_t^i$  and  $Y_t^i$  can be precisely calculated for each  $t, t=1, 2, \dots, n$ . It means that  $Y_t^i$  is not a control variable, and that a real control variable in the process is  $u_i$ .

Storage space constraints are considered only at the beginning of periods  $t$  and consequently can be formally defined as

$$\sum_{i=1}^m (X_{t-1}^i + Y_t^i) P_i \leq G \quad t=1, 2, \dots, n.$$

(6)

Let us determine the total cost  $J(u_1, u_2, \dots, u_m)$  for the inventory system described by (3)-(5). It is equal to the sum of the total costs for every product  $i$  at each period  $t$ , where the



total inventory holding cost of product  $i$  in period  $t$  is calculated with respect to the average inventory level which is equal to  $X_{t-1}^i + Y_t^i - \frac{D_i}{2n}$  and period length  $T/n$ . More formally,

$$J(u_1, u_2, \dots, u_m) = \sum_{i=1}^m J_i(u_i)$$

$$J_i(u_i) = \sum_{t=1}^n ((S_i + C_i \cdot Y_t^i) \cdot \delta_t^i + H_i \cdot (X_{t-1}^i + Y_t^i - \frac{D_i}{2n}) \cdot \frac{T}{n})$$

where  $\delta_t^i = \begin{cases} 1, & Y_t^i > 0 \\ 0, & Y_t^i = 0 \end{cases}$ .

A more simplified expression for total cost  $J$  is

$$J(u_1, u_2, \dots, u_m) = \sum_{i=1}^m S_i u_i + \sum_{i=1}^m \frac{H_i T}{n} \sum_{t=0}^{n-1} X_t^i + \sum_{i=1}^m (C_i D_i + H_i D_i \frac{T}{2n}) \quad ,$$

(7)

where we include the fact that  $\sum_{t=1}^n Y_t^i = D_i$ .

Now the following combinatorial problem on the dynamic discrete time system control process (3)-(5) (named DTSC problem) can be formulated: for control variables  $u_1, u_2, \dots, u_m$  of the process (3)-(5) find such values from  $\{1, 2, \dots, n\}$  which satisfy all storage space constraints (6) and minimize the total cost (7).

Formally speaking, it could happen that for control variables  $u_1, u_2, \dots, u_m$  there are no feasible values from  $\{1, 2, \dots, n\}$ , i.e. values which satisfy constraints (6). But, as  $X_0^i = 0, i = 1, 2, \dots, m$ , then the first ordering of each product should be realized at the beginning of period 1. Therefore, condition

$$\sum_{i=1}^m \frac{D_i P_i}{n} \leq G \quad .$$

(8)

provides that at least values  $u_1 = n, u_2 = n, \dots, u_m = n$  are feasible. In further considerations we assume that condition (8) is satisfied.

### 3. SPECIAL HEURISTICS

In this section we develop a special heuristics for solving DTSC problem approximately as defined in Section 2. The main elements of the algorithm are defined in the following way:

*The Search space  $U$ :* Space  $U$  contains all  $m$ -triples  $u = (u_1, u_2, \dots, u_m)$  such that  $u_i \in \{1, 2, \dots, n\}, i = 1, 2, \dots, m$ . It means that during a search process through space  $U$  the heuristic can generate not only feasible solutions  $u$  (where coordinates  $u_1, u_2, \dots, u_m$  satisfy storage space constraints (6)), but also unfeasible ones which do not fulfill these constraints.

*Objective functions:* The "quality" of a generated solution  $u$  is measured in two ways:

if  $u$  is feasible then its quality is measured by the corresponding value of the total cost  $J(u)$  defined by (7). Namely, a feasible solution  $u_1$  is better than a feasible solution  $u_2$  if  $J(u_1) < J(u_2)$ .

If  $u$  is infeasible then its “infeasibility gap” is measured by value  $L(u)$ , where

$$L(u) = \max_{i=1,2,\dots,n} \left( \sum_{t=1}^m (X_{t-1}^i + Y_t^i) P_i - G \right) . \quad (9)$$

The infeasible solution  $u_1$  is better than the infeasible solution  $u_2$  if  $L(u_1) < L(u_2)$ .

The heuristics is based on the local search technique. Starting from an initial solution, the best (feasible or infeasible) point from the “neighborhood” of current solution is obtained in each iteration. The obtained solution represents next searching point. If the current solution is feasible and there is no better solution in the neighborhood, the structure of this neighborhood is changing. Now, the best solution is searched again in the modified neighborhood. This principle is similar to a principle of a very well-known variable neighborhood search (VNS) metaheuristics which is used to avoid “traps” of local optima.

$\delta$ -neighborhood  $N(\delta, u^k)$  of current point  $u^k = (u_1^k, u_2^k, \dots, u_m^k)$  from space  $U$  is defined as a set of all points  $u = (u_1, u_2, \dots, u_m)$  from  $U$  such that  $u^k$  and  $u$  are different in just one coordinate, for example coordinate  $u_i^k$  and  $|u_i^k - u_i| = \delta$  is satisfied. Theoretically speaking, neighborhood  $N(\delta, u^k)$  could be empty in the case when there is no a coordinate  $i$  such that  $u_i^n + \delta$  or  $u_i^n - \delta$  belong to  $\{1, 2, \dots, n\}$ . Neighborhood structures are defined in accordance with a predefined set of natural numbers  $\delta_0, \delta_1, \dots, \delta_s$  where  $s > 1$  and  $\delta_1 < \delta_2 < \dots < \delta_s < \delta_0$ . When current point  $u^k$  is infeasible, structure  $\delta_0$  is joined, i.e. heuristic searching  $\delta_0$  neighborhood  $N(\delta_0, u^k)$ . When it is feasible, one of the  $\delta_j$  structures is joining  $j \in \{1, 2, \dots, s\}$  i.e.  $\delta_j$ -neighborhood  $N(\delta_j, u^k)$  is searched. If the current point cannot be improved, we continue searching the  $N(\delta_{j+1}, u^k)$  neighborhood. Note that in real-life problems  $n$  is much larger than  $\delta_0$  (usually  $n=365$  days) and therefore defined neighborhood structures provide non-empty neighborhoods.

*The initial solution:* The initial solution  $u^1 \in U$  can be generated in the following way: for each product  $i$  we consider independently the process (3)-(5) and the problem of minimizing the total cost for this product.

$$J(u_i) = S_i u_i + \frac{H_i T}{n} \sum_{t=0}^{n-1} X_t^i + C_i D_i + H_i D_i \frac{T}{2n} ,$$

and it refers to storage space constraints  $(X_{t-1}^i + Y_t^i) P_i \leq G$ ,  $t=1, 2, \dots, n$ . We find the optimal solution  $u_i^*$  to this problem using a total enumeration procedure. Now, the heuristics starts from  $u_1 = (u_1^*, u_2^*, \dots, u_m^*)$  as an initial solution. Although  $u^1$  represents an “ideal” point that minimizes the total cost for each product, it is usually infeasible according to storage space constraints (6). Starting from this point, the heuristics strives to generate feasible points where total costs (7) are as close as possible to the values of the costs for an ideal point.

Heuristics can be described more specifically with the following steps:

*Initialization step:* generate ideal point  $u^1 = (u_1^*, u_2^*, \dots, u_m^*)$ . If  $u^1$  is a feasible point, join  $\delta_1$  structure. If  $u^1$  is infeasible point, join  $\delta_0$  structure;

*Iteration step:* For  $k=1, 2, \dots$

- If point  $u^k$  is unfeasible, find the best feasible point  $u_{best}^f$  in the neighborhood  $N(\delta_0, u^k)$  (according to criteria function  $J(u)$ ), join the neighborhood structure  $\delta_1$  and set  $u^{k+1} = u_{best}^f$ . If there are no feasible points in the neighborhood  $N(\delta_0, u^k)$ , find the best unfeasible point  $u_{best}^f$  (according to criterion function  $L(u)$ ). If  $u_{best}^f$  is better than  $u^k$ , join the neighborhood structure  $\delta_0$  and set  $u^{k+1} = u_{best}^f$ .
- If the point  $u^k$  is feasible with joined structure  $\delta_j$  for  $j \in \{1, 2, \dots, s\}$ , find the best feasible point  $u_{best}^f$  in the neighborhood  $N(\delta_j, u^k)$ . If  $u_{best}^f$  is better than  $u^k$ , join the neighborhood structure  $\delta_1$  and set  $u^{k+1} = u_{best}^f$ . If  $u_{best}^f$  is not better than  $u^k$  or there are no feasible points in the neighborhood  $N(\delta_j, u^k)$  remain in the point  $u^k$ , i.e.  $u^{k+1} = u^k$ , and join the new neighborhood structure  $\delta_{j+1}$ .

*The stopping criterion:*

- If the current point  $u^k$  is unfeasible and there are no feasible points in the neighborhood  $N(\delta_0, u^k)$ , stop if the best unfeasible point  $u_{best}^f$  from the neighborhood is worse than the point  $u^k$ .
- If the point  $u^k$  is feasible with joined structure  $\delta_s$  stop if the best unfeasible point  $u_{best}^f$  from the neighborhood  $N(\delta_s, u^k)$  is worse than the point  $u^k$  or there are no feasible points in this neighborhood.

#### 4. NUMERICAL RESULTS

The implementation of special heuristics, described in Section 3, and VNS algorithm, described in Section 4, was realized in *Visual Basic for Application*, and it uses intermediate results obtained from the model developed in *Excel spreadsheets*. All experiments were performed on *Windows 7 Ultimate* operating system on a *Pentium (R) Dual-Core CPU T4200* processor with 4.00 GB of RAM and 2.00 GHz.

In order to investigate the behavior of the special heuristics and VNS algorithm, and compare their efficiency, they were preliminarily tested on a hypothetical DTSC problem with  $m=102$  products, where the inventory management process is considered during period  $T=1$  year which is divided into  $n=365$  days. The total available storage space is equal to  $G=3500$  m<sup>2</sup>. Ranges of other input data for all products are given in Table 1. The optimal solution to this problem is not known in advance.

**Table 1:** Ranges of input data

	$D_i$ [unit]	$P_i$ [m <sup>2</sup> /unit]	$S_i$ [\$/order]	$C_i$ [\$/unit]	$H_i$ [\$/unit/day]
range	[1000; 10000]	[0.10; 2.00]	[1; 15]	[0; 100]	[3; 7]

We performed four groups of numerical experiments with  $k_{max} = 5, 10, 15, 20$ . For each of these values the VNS algorithm was applied 10 times generating an initial solution by the deterministic procedure, described in Section 4. Special heuristics was applied once for each value, because the results were the same for the same value of parameter  $k_{max}$ , generating an initial solution by the same deterministic procedure as by the VNS algorithm. The stopping criterion for the VNS algorithm is more than 1000 iterations between two improvements of objective function (7). The stopping criterion for special heuristics is described in Section 3. The corresponding best values of the objective function (7) as well as the average execution CPU time for both solving techniques are presented in Table 2.

The numerical experiments show that in all cases the results obtained using the special heuristics, as well as the duration of execution time, are better than those obtained with the VNS based algorithm. Taking into account only the results of special heuristics we could not

notice that either the quality of obtained objective function values or the duration of execution time are dependent on values of  $k_{\max}$ .

**Table 2:** Numerical results

k	Solving technique	Initial solutions	Best value of the objective cost function	Average value of the objective cost function	Time of search for column 3 (sec)	Average time of search for column 4 (sec)
	1	2	3	4	5	6
5	Special heuristics	Deterministic	119.145,02	119.145,02	0:01:57	0:01:57
	VNS algorithm	Deterministic	120.960,53	122.857,79	0:05:05	0:06:42
10	Special heuristics	Deterministic	119.565,54	119.565,54	0:01:02	0:01:02
	VNS algorithm	Deterministic	121.619,03	124.585,00	0:02:11	0:03:06
15	Special heuristics	Deterministic	118.734,27	118.734,27	0:00:43	0:00:43
	VNS algorithm	Deterministic	123.669,93	127.404,19	0:01:41	0:02:02
20	Special heuristics	Deterministic	116.979,20	116.979,20	0:00:34	0:00:34
	VNS algorithm	Deterministic	124.150,54	129.120,54	0:01:09	0:01:36

## 5. CONCLUSION

In this paper a static time-continuous multiproduct EOQ-based inventory problem with limited storage space is modelled as a combinatorial optimization problem in the corresponding dynamic discrete time system control process. To solve this model we have developed special heuristics and a VNS-based algorithm. Preliminary numerical results show that both algorithms could be efficiently applied to problems of smaller dimensions and that results obtained using special heuristics are better than those obtained with the VNS based algorithm.

Further research could be directed toward more systematic research into the algorithm efficiency in real-life problems with larger dimensions, i.e. a model with increased number of units and constraints. Also, some other special heuristics, VNS-based or hybrid heuristic approaches for solving the described model could be developed.

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# AN INTELLIGENT ROUTE OPTIMIZATION SYSTEM FOR EFFECTIVE DISTRIBUTION OF PHARMACEUTICAL PRODUCTS

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## Abstract

**Purpose of this paper:** This paper proposes an intelligent route optimization system (IROS) to maintain the quality of pharmaceutical products and improve order-fulfilment rate. Through optimizing the vehicle routing in the distribution process, service quality and customer satisfaction can be enhanced by the means of adopting information and communication technologies (ICT).

**Design/methodology/approach:** The IROS is developed by integrating ICT and an artificial intelligence (AI) technique, i.e. genetic algorithm (GA). GA is used to optimize the vehicle routing for the distribution of pharmaceutical products. Since such products have to be stored in a stable temperature range, real-time environmental data is collected automatically through a wireless sensor network. By doing so, the route can be re-optimized in real-time in order to minimize the product deterioration rate due to improper temperature monitoring.

**Findings:** The results indicate that the IROS helps in improving the visibility of pharmaceutical products through real-time monitoring. In addition, the optimal path distributing such products can be suggested for logistics service providers (LSPs) to minimize delivery time, and hence improve the operational efficiency and customer satisfaction.

**Value:** An intelligent system is presented to provide the functionalities of real-time monitoring and dynamic routing optimization under a multi-temperature joint distribution environment. Through a case study conducted in a pharmaceutical distribution centre located in Hong Kong, it is shown that the proposed IROS is valuable in providing real-time monitoring to maintain the product quality, and in formulating appropriate routing to distribute such products to end-customers effectively.

## 1. INTRODUCTION

In recent years, the global demand for pharmaceutical products has hugely increased because of growing aging population and the rise of infectious diseases. Products which have a temperature sensitive nature and short product life-cycle require a seamless pharmaceutical supply chain to maintain the prescribed product quality for the end users. In general, the effectiveness of the supply chain greatly relies on collaboration between multiple parties in a complicated network, such as suppliers, distributors, and customers (Susarla and Karimi, 2012). Ownership transfer is a critical point in the supply chain and may lead to the products not being sufficient controlled and monitored during the distribution process (Stadtler, 2015). Figure 1 shows two existing challenges in the current pharmaceutical industry. Since pharmaceutical products have multi-temperature characteristics, warehouses typically are divided into freezing, chilling, and general storage sections so as to meet various handling requirements and maintain a good product quality. In order to maximize the truck load, cooling boxes using phase-change materials, such as ice pads, are used to temporary handle the pharmaceutical products so as to formulate a multi-temperature joint distribution. The first problem is the lack of real-time product monitoring during transportation. Customers may not be able to see the damaged or deteriorated pharmaceutical products due to fluctuations in the environmental conditions.

The second problem is that the distribution team will complete all delivery orders no matter which products have deteriorated so that the transportation costs will be over-estimated, and the distribution routing is ineffective for logistics service providers. Thus, it is essential to develop a system to determine a dynamic routing solution with real-time product monitoring during the transportation in order to minimize the transportation costs and improve customer satisfaction. In this paper, an intelligent route optimization system (IROS) is proposed with the adoption of latest ICT and GA techniques to formulate the dynamic routing management with the shortest travelling distance.

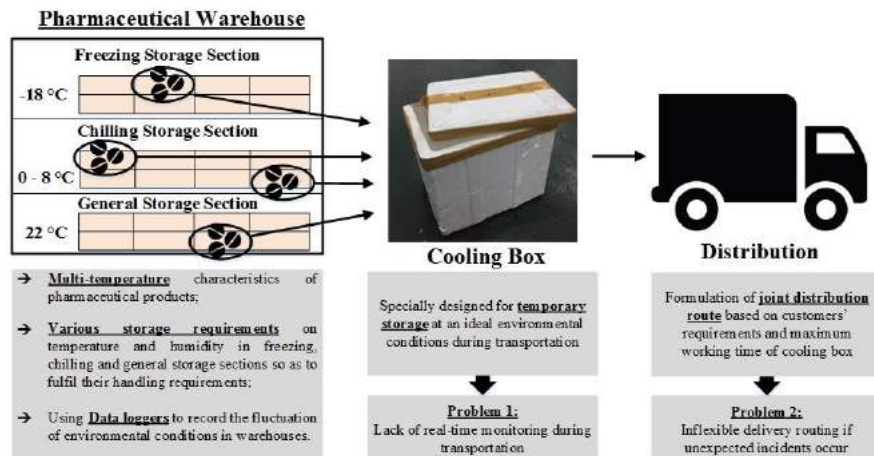


Figure 1 Existing problems in transportation of pharmaceutical products

This research paper is divided into six sections. Section 2 is a literature study that covers a review of current transportation operation environment, ICT adoption, and GA based routing approaches. This is followed by the system architecture of IROS in Section 3. Section 4 is a case study conducted to validate the feasibility of the proposed system. Results and discussion in adopting the IROS are discussed in Section 5. Section 6 gives the conclusions.

## 2. LITERATURE REVIEW

In recent years, there has been an emerging trend of a pharmaceutical distribution being applied to manage temperature-sensitive drugs (Rossetti et al., 2011). Transportation has played an important role in managing the complicated physical distribution between various supply chain parties, such as express couriers, multi-modal transport operators, and third-party logistics service providers (Crainic and Laporte, 1997). It is a major cost item in overall logistics costs, varying from around 25% to upward of 50% (Perego et al., 2011). Over the past few years, the logistics industry has experienced fierce competitiveness so that the leading factors of cost compression and service level are important in selecting the most appropriate transportation service providers from the users' viewpoints (Lemoine and Dagnæs, 2003). Hence, with effective transportation management, logistics companies can benefit from cost reduction and improvements in reputation and operational efficiency. Many researchers have presented several vehicle routing methods in order to improve the effectiveness and efficiency of the delivery process (Shen et al., 2009; Dondo et al., 2011; Lahyani et al., 2015). However, limited attention has been paid to developing dynamic routing planning and real-time monitoring during pharmaceutical distribution.

The rapid growth of information and communication technologies (ICT) has been widely applied in the logistics industry in order to enhance the effectiveness and organization of supply chain activities. ICT adoption can bring both tangible (i.e. operational efficiency) and intangible (i.e. company reputation) benefits to companies (Perego et al., 2011). As a consequence, better supply chain management can be achieved by implementing the latest ICT, such as tracking and tracing systems. In practice, the techniques of radio frequency identification (RFID) and wireless sensor network have been maturely developed to collect product information automatically (Ruiz-Garcia et al., 2008; Jedermann et al., 2009). RFID

is a state-of-the-art technology to collect identities through three main components, i.e. transponders, transceivers, and computers, with corresponding middleware. It can be further integrated with other sensor technologies, such as temperature loggers, so as to establish product monitoring during the transportation. However, by using such technologies, customers can only view the information after completion of the transportation operations. In order to provide a real-time signal transmission functionality, Internet of Things (IoT) is therefore proposed to connect the pervasive items with their identity and sensor data to achieve a common objective, such as data analytics, through the Internet (Atzori et al., 2010). Under an IoT environment, a real-time monitoring system can be designed and developed in the pharmaceutical distribution process, which is still absent in the existing literature. Hence, the visibility of pharmaceutical products can be greatly increased, and the collected data can be used to aid routing planning and other decision support processes.

To solve complex optimization problems, the GA, which is a heuristic approach, is deemed to be a promising technique based on the idea of natural evolution (Renner and Ekárt, 2003). Since effective routing planning involves complicated considerations of distribution locations, types of goods, and vehicles, the application of GA can develop an optimal solution based on population size and other stopping criteria (Baker and Ayechew, 2003). It has been widely used in the area of vehicle routing problems (VRPs) in suggesting an appropriate routing solution. Ombuki et al. (2006) discussed the vehicle routing problem with time windows by integrating the GA and Pareto ranking technique to formulate an effective multi-objective routing solution. Lin et al. (2014) developed a decision support system to establish real-time re-optimization of routing planning in order to maintain the desired service level with fuzzy time windows. However, few studies have considered the effective working time of cooling boxes in transportation, so that the desired handling environment may not be maintained.

To summarize, effective management in pharmaceutical distribution is important in the current logistics industry. Limited attention has been paid in formulating dynamic routing planning and product monitoring for distributing pharmaceutical products. Through integrating ICT techniques and GA, products can become under real-time monitoring and the delivery route can be dynamically adjusted if any unexpected incidents occur. This paper makes use of latest ICT adoption and GA to establish multi-temperature joint distribution routing planning in order to optimize the effectiveness and efficiency of distribution practice.

### **3. SYSTEM ARCHITECTURE OF IROS**

To improve pharmaceutical distribution operations, an intelligent route optimization system (IROS) is proposed which provides real-time product monitoring and dynamic routing planning by optimizing the travelling distance. Figure 2 shows the system architecture of IROS, which consists of three modules: (i) automatic data collection module (ADCM), (ii) mathematical modelling module (MMM), and (iii) dynamic route optimization module (DROM).

#### **3.1 Automatic Data Collection Module (ADCM)**

In the ADCM, a cloud database is applied to store collected data from the warehouse management system (WMS) and SensorTag CC2650. On the one hand, customer orders, including order quantity, delivery data and handling requirements, are created in WMS. The corresponding information, such as storage bin locations, can be retrieved to support the outbound logistics operations. On the other hand, the pharmaceutical products are put in cooling boxes for delivery with a SensorTag CC2650 so as to collect and transmit the real-time environmental sensor data to the cloud database. The collected data can be stored in an organized format to support further decision making processes. In addition, if any unexpected fluctuation of environmental conditions occurs, such as temperature, alert messages can be sent to the warehouse manager to decide on follow-up actions.



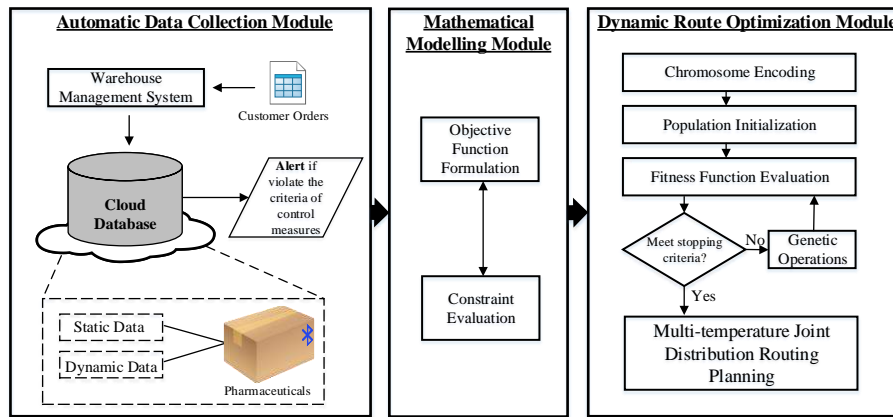


Figure 2 System architecture of IROS

### 3.2 Mathematical Modelling Module (MMM)

In the MMM, the collected data are used to formulate the objective function and corresponding constraints in order to develop dynamic routing planning for pharmaceutical distribution. The notations of the proposed system are presented in Table 1. The objective function is to minimize the total travelling distance from the warehouse to the final customer location. In order to generate an appropriate delivery route, the constraints are set based on seven criteria. They are (i) effective working time of the cooling box, (ii) volume limit of vehicle, (iii) weight limit of vehicle, (iv) ensuring that all customers' orders are fulfilled, (v) ensuring the balance of locations' entry and exit, (vi) ensuring the balance of warehouse's entry and exit, and (vii) ensuring the route continuity. Hence, these objective function and constraints can be used to determine the optimal route by GA.

Table 1 Notation in the MMM

Notation of Indices and Parameters		Definition
$v$		Index of vehicle
$V$		Set of all vehicles
$i, j$		Index of customer location
$N$		Set of all customer location
$d_{ij}$		Euclidean distance between location $i$ and $j$
$x_{ij}^v$		Covering from location $i$ to $j$ by vehicle $v$

Objective Function:

$$\text{Min. Distance} = \sum_{v \in V} \sum_{i \in N} \sum_{j \in N} d_{ij} x_{ij}^v \quad (1)$$

### 3.3 Dynamic Route Optimization Module (DROM)

Based on the collected data and defined objective function with the constraints, the GA is applied to suggest the optimal delivery route for pharmaceutical distribution. MATLAB is used to calculate the GA iterations and conduct a number of simulation experiments by using different GA settings. In addition, the effective working time for the cooling box should be investigated to formulate the constraint (i) as mentioned above.

In IROS, the route sequence and division are encoded by real integer and binary numbers respectively. The route sequence denotes that tours will be created to visit all requested customer locations, while route division denotes that the tours will be divided into numerous sections so as to complete the delivery, within the limitation, by several vehicles. Figure 3 shows the illustration of the mentioned chromosome encoding process in IROS. In the route division part, the binary number 1 indicates the separation point between the tours, such as from  $L_m$  to  $L_n$  and  $L_i$  to  $L_j$ . The separation decision is made by considering the aforementioned seven constraints. The GA iteration will be ended based on the stopping criteria, otherwise the GA operations, including crossover, mutation, and repair, will be conducted and the fitness function will be re-evaluated. Eventually, the proposed system

will calculate various tours in order to complete all customers' orders. As a consequence, the pharmaceutical products with various handling requirements can be shipped and handled so as to formulate effective multi-temperature joint distribution routing planning.

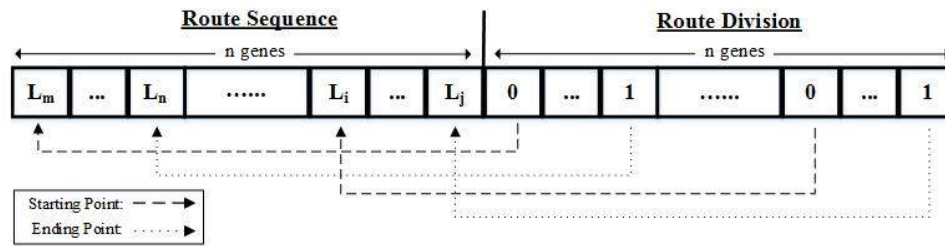


Figure 3 Illustration of chromosome encoding in IROS

#### 4. CASE STUDY

This section consists of (i) company background, (ii) problems in PH Limited, and (iii) implementation of IROS in PH Limited.

##### 4.1 Company Background

PH Limited is a Hong Kong-based third party logistics service provider with professional in the distribution hub operation, distribution logistics and value added services for multinational and local brand owners. Its business philosophy is to provide the best logistics services to their customers. It owns its own warehousing facilities and a fleet of vehicles to offer various handling conditions for bulk and products which require complex logistics operations. It also has a pharmaceutical warehouse which is accredited by Good Distribution Practice (GDP) and Good Manufacturing Practice (GMP) in managing biological and pharmaceutical (B&P) products. Moreover, PH Limited provides a variety of outsourced value-added services so that their customers can reduce the manpower for the non-core business sectors, including repackaging, product customization, order processing, and supply chain management. Therefore, the company provides one-stop logistics services, especially for pharmaceutical products, with temperature-controlled warehouses and trucking fleet.

##### 4.2 Existing problems in PH Limited

In order to meet all handling requirements from their customers, PH Limited provides refrigerated facilities during the warehousing and transportation of pharmaceutical products. The storage conditions for pharmaceutical products are divided into freezing ( $-18^{\circ}\text{C}$ ), chilling ( $2^{\circ}\text{C}$ ) and temperature-controlled ( $22^{\circ}\text{C}$ ) sections. However, the conditions in typical refrigerated trucks are kept at a certain temperature which is inflexible with regard to the type of products. In view of that, most logistics service providers apply a cooling box in transportation where the storage conditions can be adjusted by the number of ice pads and thickness of the Styrofoam layer. Furthermore, using a cooling box in transportation can improve the utilization of truck loading so that the transportation cost can be greatly reduced. However, the vehicles are required to distribute the goods to various customers' locations, and there is no dynamic delivery routing management to handle unexpected incidents, such as sudden fluctuation of temperature in a cooling box. In practice, certain monitoring systems have been installed to monitor the environmental conditions on the entire trucks. It is not sufficient to keep tracking the goods conditions in real-time. Therefore, there is a need to implement the IROS in PH Limited in order to monitor the real-time product conditions at the item level and suggest the optimal delivery route for the vehicles.

##### 4.3 Implementation of IROS in PH Limited

In this section, the implementation of IROS in the transportation system of PH Limited, in improving the effectiveness and efficiency of pharmaceutical distribution, is discussed. In addition, assumptions are made in the implementation, i.e. identical volume and weight capacities of the trucks, standard sizes of pharmaceutical products, and similar effective

working time of all cooling boxes. The implementation is divided into three stages, namely (i) data collection, (ii) GA settings, and (iii) prototype routing formulation.

#### (i) Data collection

In PH Limited, truck information and product information are required to develop the GA calculation. There are 2 trucks available for handling orders with volume of 2,500,000cm<sup>3</sup> and weight capacity of 2,500 kg each. The pharmaceutical products are packed in cooling boxes where the volume ranges from 210,000 cm<sup>3</sup> or 504,000 cm<sup>3</sup> for distribution. The best fit lines of the effective cooling box working time are investigated with respect to number of ice pads, as in Figure 4. Based on customer requirements, the most suitable cooling box setting will be selected to handle the products. In addition, the customer locations are represented by the x-coordinate and y-coordinate for illustration, while the pharmaceutical warehouse is located at coordination (0, 0).

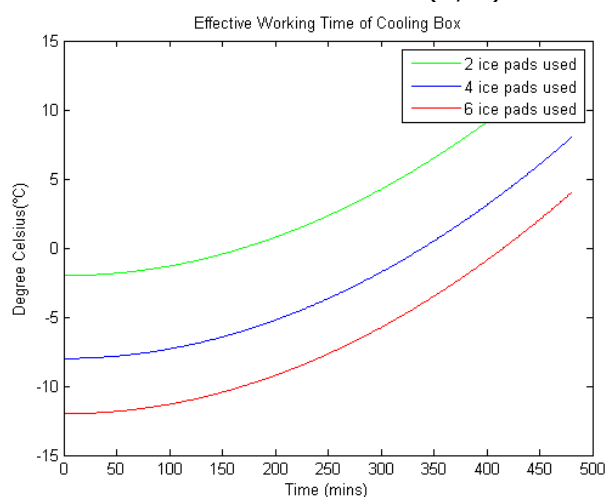


Figure 4 Best fit lines of effective working time of cooling box

On the other hand, the real-time environmental data are collected by using SensorTag CC2650. Implementing with Platform as a Services (PaaS), the sensor data can be transmitted and upload to a cloud database in the format of JSON. The data of ambient temperature, object temperature, humidity, lighting level, and pressure are collected with specific threshold values to define the acceptable ranges during transportation. Once the criteria of control measures are violated, an alert will be sent to the warehouse manager and corresponding staff immediately, in order that the delivery route can be adjusted to prevent the delivery of deteriorated products to customers.

#### (ii) GA settings

Since the collected data are stored in the cloud database, GA is applied to determine the optimal delivery sequence with real-time re-optimization. In this research, MATLAB is used to perform the GA calculations and to generate the delivery path. The population size, crossover rate, and mutation rate are 100, 0.75, and 0.06 respectively. Two sets of generations, namely 600 and 1500, are investigated to compare their fitness values as shown in Figures 5 and 6.

#### (iii) Prototype routing formulation

Based on the above study, the solution of 1500 generations is adopted to formulate the delivery sequence for the transportation team. Figure 7 shows the delivery sequence for one of the vehicles, and is a complete routing starting from and ending at the pharmaceutical warehouse. The effective working time of certain cooling boxes is considered. If there are any unexpected incidents for transporting particular goods, the delivery route will be re-optimized to skip that customer's delivery orders. Meanwhile, the warehouse management and transportation team will report this issue to customers. Therefore, another delivery can be arranged immediately for those particular items to minimize the effect of the incident.

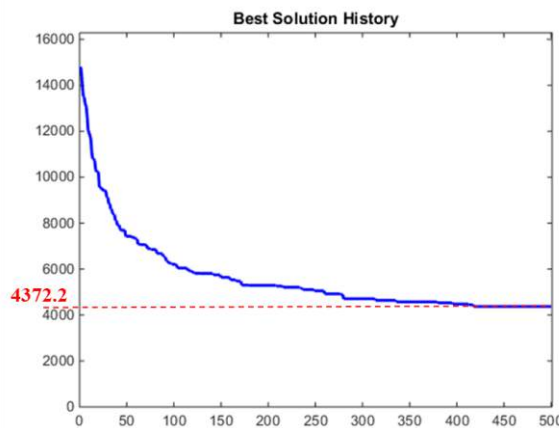


Figure 5 Fitness value by 600 generations

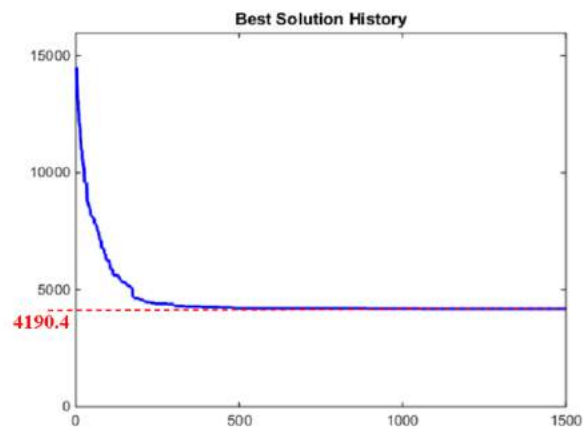


Figure 6 Fitness value by 1500 generations

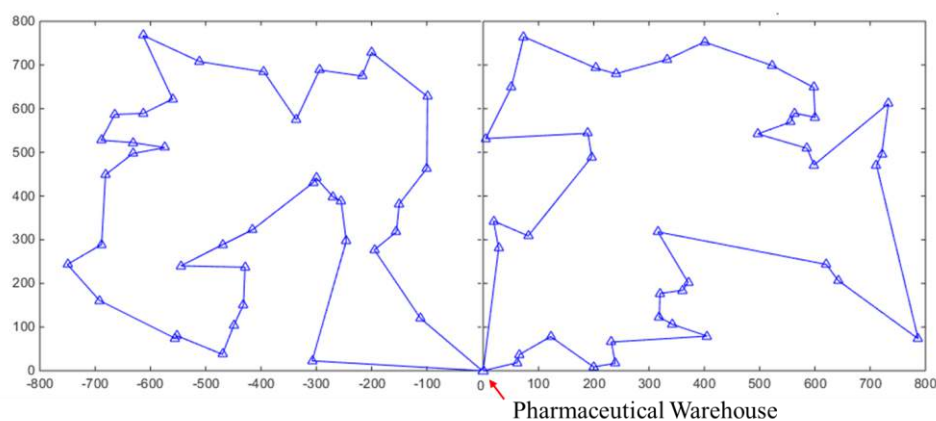


Figure 7 Illustration of delivery sequence in IROS

## 5. RESULTS AND DISCUSSION

This paper presents IROS to establish a dynamic delivery route and real-time product monitoring for pharmaceutical distribution with the adoption of sensor technology and GA. According to the implementation of IROS in PH Limited, the average travelling distance is 4190.4 metres which is shorter than in previous routing planning. The truckers, back office of the logistics service providers, and customers can get real-time information on the products. Once any adjustment of delivery route is suggested, the truckers will be informed with the clear information about the updated route. As a consequence, two advantages are found after adopting the proposed system, namely improvement in (i) operational efficiency and (ii) customer satisfaction. Compared with the previous routing planning in which the delivery routes are planned before the distribution, dynamic routing planning provides a great degree of flexibility in handling temperature-sensitive products. The errors in transportation, such as distributing deteriorated products to customers, can be avoided. The transported products can be ensured to be at the acceptable quality until delivery of the products to customers. Hence, the efficiency of the entire transportation operation can be improved. On the other hand, information on fluctuations of environmental conditions are visible and can be shared between various parties. Corresponding adjustments can be decided to minimize the effect of the unexpected incidents. With accurate routing planning, the estimated arrival time can also be provided to the customers. Consequently, customer satisfaction and company reputation will be enhanced.

## 6. CONCLUSIONS

Pharmaceutical distribution is time critical and in quality-driven logistics operations, and the products themselves have a variety of suitable storage conditions. In traditional LSPs, it may be difficult to control the environmental changes and formulate an appropriate delivery route. The products may be easily deteriorated or even damaged under unknown

situations. Furthermore, LSPs have to bear high risks in transporting such products, such as compensation for damaged products. This paper proposes an intelligent route optimization system (IROS) to support warehouse and transportation management on the issue of product monitoring and routing planning. IROS integrates real-time product information and route planning to formulate a dynamic route re-optimization by adopting the latest ICT and GA approaches to collect and analyse the data automatically. The flexibility of route planning is greatly improved in meeting all customer requirements. The validation of the proposed system was studied in a third-party logistics service provider in Hong Kong. After the pilot study in the case company, the operational efficiency and customer satisfaction were increased. Therefore, it is proven that the proposed system can significantly contribute to enhancing pharmaceutical logistics, especially in aiding transportation management personnel in planning the delivery route and in monitoring the transported goods. In order to further evaluate the IROS model, future research work can be considered to conduct more cases in handling various products and in cooling box design for enhancing pharmaceutical distribution operations.

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# ANALYTICAL MODELS FOR MEAN ESTIMATIONS OF TRAVEL TIME AND ENERGY CONSUMPTION PER TRANSACTION IN A SHUTTLE BASED STORAGE AND RETRIEVAL SYSTEM

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## ABSTRACT

The aim of this study is to present analytical models for mean (expected value) calculations for travel time of shuttles and lifts per transaction as well as mean energy consumption calculations per transaction in a shuttle-based storage and retrieval system (SBS/RS). Recent advances in automation technology has created a high variety of warehouse automation technologies one of which is SBS/RS (Lerher et al. 2013; Lerher et al., 2015a-2015b). The high variety of warehouse automation results with the confusion of warehouse managers on identifying the right technology for their companies. Therefore, development of analytical models producing several performance measures from the system is critical to evaluate the system's performance promptly. By the analytical models provided in this study, systems' performance can be evaluated promptly by changing the input parameters (e.g. discrete travel lengths, velocity of vehicles, acceleration/deceleration of vehicles, number of tiers, metrics, etc.) affecting the performance of the systems. The methodology illustrated in this paper can also be utilized in any systems having straight and discrete travel pattern with equal distance stop points (e.g. in subway systems train travel estimations, etc.). It is found that the proposed analytical results produce reasonable accurate results, typically less than 0.09%, when we compare them with the simulation results.

**Keywords:** Automated warehousing, automated storage and retrieval system, SBS/RS

## INTRODUCTION

Recent developments in automation technology has created warehouse automation technologies for a high variety of flexible designs. One such recent technology is SBS/RS whose traditional design is illustrated in Figure 1.

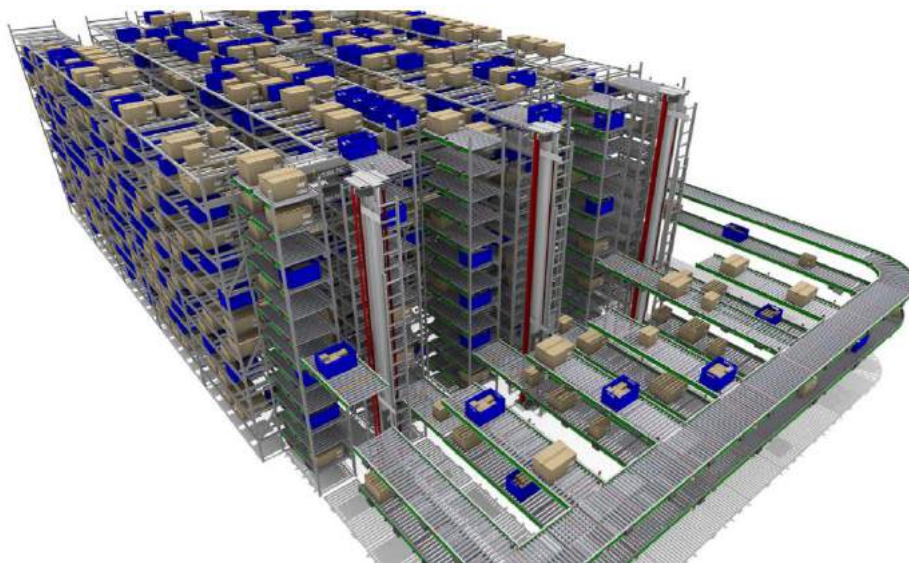


Figure 1: An SBS/RS warehouse (Dematic Multishuttle 2 White Paper, 2013)

SBS/RS is developed as an alternative system to the “traditional” mini-load AS/RS crane. It can provide high transaction rate compared to a mini-load AS/RS. Loads are stored and removed from the shelves at high speed by shuttles and the load handling equipment of the shuttle is designed for short handover times.

Typically, an SBS/RS design's input parameters include physical design of the rack (i.e., number of tiers, bays) as well as velocity profiles of the lifts and shuttles. In order to decide on a system's design, we develop an analytical model that produces critical performance measures, specifically the mean of the travel time of lifts and shuttles  $-E(T)$  and the mean amount of energy consumption per transaction in an SBS/RS, by considering different input design parameters.

## LITERATURE REVIEW

There are few studies in literature on SBS/RS. We provide some of the related ones here.

Marchet et al. (2012) present an open queuing network model to estimate the average waiting time and cycle time for only retrieval transactions. The model effectiveness in performance estimation is validated via simulation. Due to not considering storage processes in the system, the study lacks realism making it a practical tool.

Marchet et al. (2013) use simulation to highlight the main design trade-offs for SBS/RS for several warehouse design scenarios involving tier-captive shuttle carriers. Four performance measures observed from the system are: utilizations of lifts and shuttles, average flow time, waiting times, and cost of limited number of pre-defined rack designs.

Lerher (2013) considers energy efficiency design concept in the SBS/RS design. The proposed model present several warehouse designs including velocity profiles of lifts and shuttles along with the amount of energy (electricity) consumption and CO<sub>2</sub> oscillation, and the throughput capacity in the system.

Lerher et al. (2015a) presented closed-form travel time models for estimating average travel (cycle) time for lifts and shuttles in SBS/RS. The proposed models consider the operating characteristics of the elevator's lifting table and the shuttle carrier including acceleration and deceleration delays. The models estimate mean travel (cycle) time for single and dual command cycles, separately. The developed models are tested by simulation models. This study does not consider energy related calculations as well as variance estimations for transactions.

Lerher et al. (2015b) used a simulation model to evaluate the performance of an SBS/RS by utilizing a detailed modelling approach. The objective of this study is to show the benefits of SBS/RS design resulting with a reduction of mean cycle time of transactions and consequently an increase of throughput capacity in the system.

Tappia et al. (2016) study a semi-open queuing network for modeling an SBS/RS. They solve the network via the Matrix Geometric Method and estimate the queue related performance measures from the system. They validate the results via simulation and present the APE values.

## STUDIED SBS/RS ASSUMPTIONS

The SBS/RS assumptions that are considered in the study are listed below:

- In each tier, there are two buffer areas to discharge and charge the loads. And they are utilized randomly.
- The lifts and shuttles work with the first-in-first-out (FIFO) scheduling rule.
- The distance between two adjacent bays is considered to be equal with the travel distance between the first bay and the buffer location in each tier.
- Loading and unloading delays are not considered in the models.
- A pure random storage policy is assumed in the model.
- The dwell point of lifts/shuttles are assumed to be the points where they complete their last transaction.
- Acceleration and deceleration delays of lifts/shuttles are considered to be the same ( $a_S=d_S$  and  $a_L=d_L$ ).

## TRAVEL TIME CALCULATIONS

Travel time is function of the velocity profiles of the shuttles and lifts. Therefore, it is critical to know whether lift/shuttle is accelerating, decelerating or travelling at a constant velocity (the maximum speed). In Figures 2a-2b, velocity versus time graphs are shown based on two cases. For instance, in Figure 2a (Case I), the shuttle/lift cannot reach its maximum velocity due to relatively short travel distance while in Figure 2b (Case II), the shuttle/lift can reach its maximum velocity due to relatively long travel distance. The related travel time calculations are given below:

$$D = V_{top} \cdot t_1 \quad (1)$$

$$(V_{top} \text{ or } V_{max}) = a \cdot t_1 \quad (2)$$

$$t_1 = \sqrt{D/a} \quad (3)$$

$$\text{Total Travel Time} = 2 \cdot t_1 + t_3 = \frac{D}{V_{max}} + \frac{V_{max}}{a} \quad (4)$$

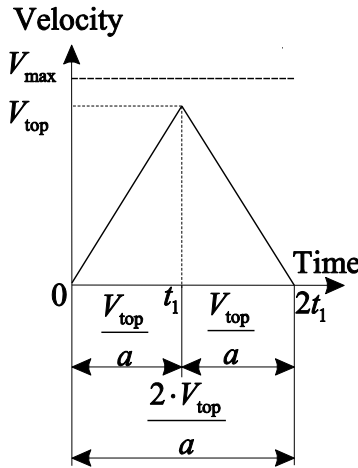


Figure 2a: Case I

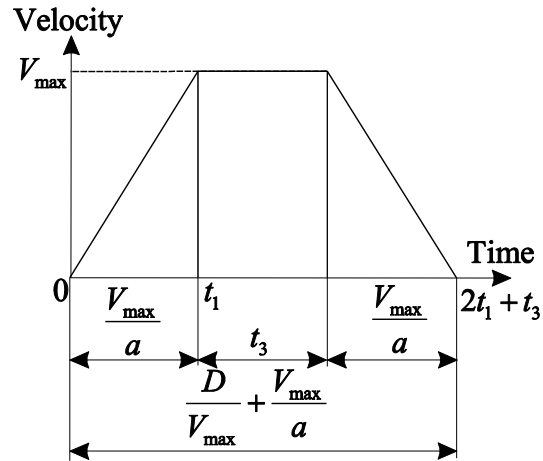


Figure 2b: Case II

## EXPECTED VALUE (MEAN) CALCULATIONS FOR TRAVEL TIME ESTIMATION OF SHUTTLES

Lift/shuttle follows discrete travel time pattern. Hence, we consider the mean of travel time of lifts/shuttles as discrete random variables, say  $X$ . It is well known that the mean of a discrete random variable ( $X$ ) can be calculated by (5).

$$\mu = E(X) = \sum_x x f(x) \quad (5)$$

where  $f(x)$  is the probability mass function of the random variable of  $X$ . The mean travel time of a shuttle can be calculated by considering four possible cases summarized by (7)-(10). Note that since a random storage policy is considered, the probability of selecting a storage location is equally likely (discrete uniform distribution) which is  $1/n$  where  $n$  is the number bays. Hence, the mean travel time of a shuttle per transaction is calculated by (6):

$$E(T) = \frac{1}{4} \cdot [E(S_1) + E(S_2) + E(R_1) + E(R_2)] \quad (6)$$

$$E(S_1) = \frac{1}{n} \sum_{i=0}^n t_{0i} \quad (7)$$

$$E(S_2) = \frac{1}{n^2} \sum_{i=1}^n \sum_{j=1}^n (t_{i0} + t_{0j}) \quad (8)$$

$$E(R_1) = \frac{1}{n} \sum_{i=1}^n (t_{0i} + t_{i0}) \quad (9)$$



$$E(R_2) = \frac{1}{n^2} \sum_{i=1}^n \sum_{j=1}^n (t_{ij} + t_{j0}) \quad (10)$$

Where  $t_{ij}$  is the travel time from the buffer location,  $i^{\text{th}}$  bay, to the  $j^{\text{th}}$  storage bay. Note that 0 (zero) is considered to be the buffer location.

### MEAN CALCULATION FOR TRAVEL TIME OF LIFT

We used method a Discrete-Time Markov-Chain (DTMC) to calculate the mean of travel times. We assumed that if the requested transaction is at the first tier, the lift is not utilized. We develop a state-based approach via DTMC to calculate the mean of travel time of the lift. We denote the states as  $(i, j, k)$  where  $i$  is the current tier of the lift ( $i = 1, 2, \dots, N_t$ ),  $j$  is the transaction type, storage (1) or retrieval (2) ( $j = 1, 2$ ), and  $k$  is the transaction's tier address ( $k = 1, 2, \dots, N_t$ ). The transaction probability matrix for the states,  $P$  is given by (11).

$$P = \begin{bmatrix} A_1 & & & & & & & & & \\ & S_1 & & & & & & & & \\ B_1 & & & & & & & & & \\ R_1 & & & & & & & & & \\ & & A_2 & & & & & & & \\ & & S_2 & & & & & & & \\ & & B_2 & & & & & & & \\ R_2 & & & & & & & & & \\ & & & A_3 & & & & & & \\ & & S_3 & & & & & & & \\ & & & B_3 & & & & & & \\ R_3 & & & & & & & & & \\ & & & & \ddots & & & & & \\ & & \vdots & & & \ddots & & & & \\ & & & & & & \ddots & & & \\ \vdots & & & & & & & A_{N_t} & & \\ & & & & & & & S_{N_t} & & \\ & & & & & & & & B_{N_t} & \\ R_{N_t} & & & & & & & & & \end{bmatrix} \quad (11)$$

where,  $A_i, B_i, S_i, R_i$  are defined by (12)-(15) respectively:

$$A_i = (i, 1, 1) \begin{bmatrix} (i, 1, 1) & (i, 1, 2) & \dots & (i, 1, N_t) & (i, 2, 1) & \dots & (i, 2, N_t) \\ \frac{1}{2} \times \frac{1}{N_t} & \frac{1}{2} \times \frac{1}{N_t} & \dots & \frac{1}{2} \times \frac{1}{N_t} & \frac{1}{2} \times \frac{1}{N_t} & \dots & \frac{1}{2} \times \frac{1}{N_t} \end{bmatrix} \quad (12)$$

$$B_i = (i, 2, 1) \begin{bmatrix} (i, 1, 1) & (i, 1, 2) & \dots & (i, 1, N_t) & (i, 2, 1) & \dots & (i, 2, N_t) \\ \frac{1}{2} \times \frac{1}{N_t} & \frac{1}{2} \times \frac{1}{N_t} & \dots & \frac{1}{2} \times \frac{1}{N_t} & \frac{1}{2} \times \frac{1}{N_t} & \dots & \frac{1}{2} \times \frac{1}{N_t} \end{bmatrix} \quad (13)$$

$$S_i = \begin{bmatrix} S_{i2} & & & & & \\ & S_{i3} & & & & \\ & & S_{i4} & & & \\ & & & \ddots & & \\ & & & & \ddots & \\ & & & & & S_{iN_t} \end{bmatrix} \quad (14)$$

$$R_i = \begin{matrix} (i,2,2) \\ (i,2,3) \\ \vdots \\ (i,2,N_t) \end{matrix} \begin{bmatrix} \frac{1}{2} \times \frac{1}{N_t} & \frac{1}{2} \times \frac{1}{N_t} & \cdots & \frac{1}{2} \times \frac{1}{N_t} & \frac{1}{2} \times \frac{1}{N_t} & \cdots & \frac{1}{2} \times \frac{1}{N_t} \\ \frac{1}{2} \times \frac{1}{N_t} & \frac{1}{2} \times \frac{1}{N_t} & \cdots & \frac{1}{2} \times \frac{1}{N_t} & \frac{1}{2} \times \frac{1}{N_t} & \cdots & \frac{1}{2} \times \frac{1}{N_t} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \frac{1}{2} \times \frac{1}{N_t} & \frac{1}{2} \times \frac{1}{N_t} & \cdots & \frac{1}{2} \times \frac{1}{N_t} & \frac{1}{2} \times \frac{1}{N_t} & \cdots & \frac{1}{2} \times \frac{1}{N_t} \end{bmatrix} \quad (15)$$

where  $N_t$  denotes the number of tiers. In (14) the  $S_{iN_t}$  vectors are defined by (16):

$$\begin{aligned} S_{i2} &= (i,1,2) \begin{bmatrix} (2,1,1) & (2,1,2) & \cdots & (2,1,N_t) & (2,2,1) & \cdots & (2,2,N_t) \\ \frac{1}{2} \times \frac{1}{N_t} & \frac{1}{2} \times \frac{1}{N_t} & \cdots & \frac{1}{2} \times \frac{1}{N_t} & \frac{1}{2} \times \frac{1}{N_t} & \cdots & \frac{1}{2} \times \frac{1}{N_t} \end{bmatrix} \\ S_{i3} &= (i,1,3) \begin{bmatrix} (3,1,1) & (3,1,2) & \cdots & (3,1,N_t) & (3,2,1) & \cdots & (3,2,N_t) \\ \frac{1}{2} \times \frac{1}{N_t} & \frac{1}{2} \times \frac{1}{N_t} & \cdots & \frac{1}{2} \times \frac{1}{N_t} & \frac{1}{2} \times \frac{1}{N_t} & \cdots & \frac{1}{2} \times \frac{1}{N_t} \end{bmatrix} \\ \vdots & \quad \quad \quad \vdots \quad \quad \quad \vdots \quad \quad \quad \vdots \quad \quad \quad \vdots \\ S_{iN_t} &= (i,1,N_t) \begin{bmatrix} (N_t,1,1) & (N_t,1,2) & \cdots & (N_t,1,N_t) & (N_t,2,1) & \cdots & (N_t,2,N_t) \\ \frac{1}{2} \times \frac{1}{N_t} & \frac{1}{2} \times \frac{1}{N_t} & \cdots & \frac{1}{2} \times \frac{1}{N_t} & \frac{1}{2} \times \frac{1}{N_t} & \cdots & \frac{1}{2} \times \frac{1}{N_t} \end{bmatrix} \end{aligned} \quad (16)$$

The steady-state probabilities are denoted by the vector  $\pi$  by (17) and it is obtained by (18):

$$\pi = [\pi_1 \pi_2 \dots \pi_n] \quad (17)$$

$$\lim_{m \rightarrow \infty} P^m = \begin{bmatrix} \pi_1 & \pi_2 & \cdots & \pi_l \\ \pi_1 & \pi_2 & \cdots & \pi_l \\ \vdots & \vdots & & \vdots \\ \pi_1 & \pi_2 & \cdots & \pi_l \end{bmatrix} \quad (18)$$

Once the steady-state probabilities are obtained, we can compute the mean travel time by utilizing (1)-(5).

### MEAN ENERGY CONSUMPTION CALCULATIONS FOR SHUTTLE

In the acceleration case the traction force  $F_T$ , is calculated by (19):

$$F_T = G \cdot c_r + \frac{G}{g} \cdot a_s \cdot f_r \text{ (Newton – kg m / sec}^2\text{)} \quad (19)$$

The required engine power to overcome  $F_T$  as kW is calculated by (20):

$$P_T = \frac{F_T \cdot V_{top}}{1000 \cdot \eta} \quad (20)$$

In the deceleration case, the braking force  $F_B$ , is calculated by (21):

$$F_B = \frac{G}{g} \cdot d_s \cdot f_r - G \cdot c_r \text{ (Newton – kg m / sec}^2\text{)} \quad (21)$$

The required engine power to overcome  $F_B$  as kW is calculated by (22).

$$P_B = \frac{F_B \cdot V_{top}}{1000 \cdot \eta} \quad (22)$$

In the travel case with constant velocity, the traction force is calculated by (23):

$$F_C = G \cdot c_r \text{ (Newton – kg m / sec}^2\text{)} \quad (23)$$

The required engine power,  $P_C$ , to overcome  $F_C$  as kW is calculated by (24).

$$P_C = \frac{F_C \cdot V_{max}}{1000 \cdot \eta} \text{ (kW)} \quad (24)$$

Hence, the energy (electricity) consumption for a shuttle in acceleration ( $W_A$ ) deceleration ( $W_D$ ) and constant velocity ( $W_C$ ) travel cases for shuttle can be calculated by (25)-(27) respectively:

$$W_A = P_T \cdot t_1 \text{ (kWh)} \quad (25)$$

$$W_D = P_B \cdot t_1 \text{ (kWh)} \quad (26)$$

$$W_C = P_C \cdot t_2 \text{ (kWh)} \quad (27)$$

As a result, the mean energy consumption per transaction is calculated by (28):

$$E(W_S) = E(W_A) + E(W_D) + E(W_C) \quad (28)$$

### MEAN ENERGY CONSUMPTION CALCULATIONS FOR LIFT

In the acceleration case, the lifting force is calculated by (29):

$$F_L = G + \frac{G}{g} \cdot a_L \cdot f_r \text{ (Newton - kg m / sec}^2\text{)} \quad (29)$$

where  $G$  is the gravitational force ( $G = m \cdot g$  - kg·m / sec<sup>2</sup> - Newton). The required engine power to overcome  $F_L$  as kW is calculated by (30):

$$P_L = \frac{F_L \cdot V_{top}}{1000 \cdot \eta} \quad (30)$$

In the deceleration case, the braking force is calculated by (31):

$$F_B = G + \frac{G}{g} \cdot d_L \cdot f_r \text{ (Newton - kg m / sec}^2\text{)} \quad (31)$$

The required engine power to overcome  $F_B$  as kW is calculated by (32):

$$P_B = \frac{F_B \cdot V_{top}}{1000 \cdot \eta} \quad (32)$$

In the travel case of constant velocity, the traction force is calculated by (33):

$$F_C = G \text{ (Newton - kg m / sec}^2\text{)} \quad (33)$$

The required engine power,  $P_C$ , to overcome  $F_C$  as kW, is calculated by (34).

$$P_C = \frac{F_C \cdot V_{max}}{1000 \cdot \eta} \text{ (kW)} \quad (34)$$

Hence, the energy (electricity) consumption for a lift in acceleration ( $W_{L,A}$ ), deceleration ( $W_{L,D}$ ), and in constant velocity travel case ( $W_{L,C}$ ) can be calculated by (35)-(37), respectively:

$$W_{L,A} = P_L \cdot t_1 \text{ (kWh)} \quad (35)$$

$$W_{L,D} = P_B \cdot t_1 \text{ (kWh)} \quad (36)$$

$$W_{L,C} = P_C \cdot t_2 \text{ (kWh)} \quad (37)$$

As a result, the mean energy consumption per transaction for lift is calculated by (38):

$$E(W_L) = E(W_{L,A}) + E(W_{L,D}) + E(W_{L,C}) \quad (38)$$

### EXPERIMENTAL DESIGN AND RESULTS

Experimental design scenarios for shuttles and lifts have been shown in Table 1. In this table,  $B$  is the number of bays in a tier,  $V_{max}$  is the maximum velocity of the shuttle/lift that can reach up, and  $a_s$ ,  $a_L$ ,  $d_s$ , and  $d_L$  are the acceleration/deceleration of shuttle and lift, respectively.

Table 1: Design scenarios for shuttles and lifts

Design Scenarios for Shuttles			Design Scenarios for Lifts		
$B$	$V_{max}$	$a_s = d_s$ (m/sec <sup>2</sup> )	$N_t$	$V_{max}$	$a_L = d_L$ (m/sec <sup>2</sup> )
40	2	1.5	14	1	0.5
70	5	3	17	2	1.5
100			20		

According to Table 1, we completed 12 (3×2×2) different design experiments for shuttle and lifts designs, separately. The analytical results are validated by the simulation results. The simulation is run for 10 replications hence, we provide the simulation results at %95 confidence intervals. The deviations of analytical results from the simulation results are provided by the absolute percentage error (APE), provided below.

$$APE = \frac{|E(T)_{Analytical} - E(T)_{Simulation}|}{E(T)_{Simulation}} \times 100$$

As a result of the comparison all the APE values are less than 0.03% for the shuttle estimations and less than 0.07% for the lift estimations. The results are provided in Tables 2-3.

Table 2: Comparison of analytical models with simulation results for shuttle

Scenario	$B$	$V_{\max}$	$a_s = d_s$	Analytical		Simulation		Error (%)	
				$E(T)$ (sec.)	$E(W_s)$ (kWh)	$E(T)$ (sec.)	$E(W_s)$ (kWh)	$E(T)$ (%)	$E(W_s)$ (%)
1	40	2.0	1.5	10.8	$2.6 \times 10^{-4}$	$10.8 \pm 7.0 \times 10^{-3}$	$2.6 \times 10^{-4}$	$1.7 \times 10^{-2}$	$1.3 \times 10^{-2}$
2	40	2.0	3.0	9.7	$2.7 \times 10^{-4}$	$9.7 \pm 6.8 \times 10^{-3}$	$2.7 \times 10^{-4}$	$2.1 \times 10^{-2}$	$1.5 \times 10^{-2}$
3	40	5.0	1.5	8.4	$3.1 \times 10^{-4}$	$8.4 \pm 4.5 \times 10^{-3}$	$3.1 \times 10^{-4}$	$2.1 \times 10^{-2}$	$1.6 \times 10^{-2}$
4	40	5.0	3.0	6.1	$3.2 \times 10^{-4}$	$6.1 \pm 3.4 \times 10^{-3}$	$3.2 \times 10^{-4}$	$2.9 \times 10^{-2}$	$9.8 \times 10^{-3}$
5	70	2.0	1.5	17.1	$3.3 \times 10^{-4}$	$17.1 \pm 11.9 \times 10^{-3}$	$3.3 \times 10^{-4}$	$2.4 \times 10^{-2}$	$6.4 \times 10^{-4}$
6	70	2.0	3.0	16.0	$3.4 \times 10^{-4}$	$15.9 \pm 11.6 \times 10^{-3}$	$3.4 \times 10^{-4}$	$2.2 \times 10^{-2}$	$1.3 \times 10^{-2}$
7	70	5.0	1.5	11.3	$6.3 \times 10^{-4}$	$11.3 \pm 6.2 \times 10^{-3}$	$6.3 \times 10^{-4}$	$1.4 \times 10^{-2}$	$6.5 \times 10^{-3}$
8	70	5.0	3.0	8.7	$7.2 \times 10^{-4}$	$8.7 \pm 5.2 \times 10^{-3}$	$7.2 \times 10^{-4}$	$1.6 \times 10^{-2}$	$7.7 \times 10^{-3}$
9	10	2.0	1.5	23.3	$7.2 \times 10^{-4}$	$23.3 \pm 16.7 \times 10^{-3}$	$7.2 \times 10^{-4}$	$1.4 \times 10^{-2}$	$8.1 \times 10^{-3}$
10	10	2.0	3.0	22.2	$7.7 \times 10^{-4}$	$22.2 \pm 16.5 \times 10^{-3}$	$7.7 \times 10^{-4}$	$1.8 \times 10^{-2}$	$1.2 \times 10^{-2}$
11	10	5.0	1.5	13.9	$8.0 \times 10^{-4}$	$13.9 \pm 8.0 \times 10^{-3}$	$8.0 \times 10^{-4}$	$2.3 \times 10^{-2}$	$5.4 \times 10^{-3}$
12	10	5.0	3.0	11.2	$8.3 \times 10^{-4}$	$11.2 \pm 7.1 \times 10^{-3}$	$8.3 \times 10^{-4}$	$2.2 \times 10^{-2}$	$1.5 \times 10^{-2}$

Table 3: Comparison of analytical models with simulation results for lift

Scenario	$N_t$	$V_{\max}$	$a_L = d_L$	Analytical		Simulation		Error (%)	
				$E(T)$ (sec.)	$E(W_L)$ (kWh)	$E(T)$ (sec.)	$E(W_L)$ (kWh)	$E(T)$ (%)	$E(W_L)$ (%)
1	14	1.0	0.5	6.8	$1.5 \times 10^{-3}$	$6.8 \pm 6.5 \times 10^{-3}$	$1.5 \times 10^{-3}$	$3.50 \times 10^{-2}$	$6.4 \times 10^{-2}$
2	14	1.0	1.5	4.8	$1.1 \times 10^{-3}$	$4.8 \pm 5.1 \times 10^{-3}$	$1.1 \times 10^{-3}$	$1.42 \times 10^{-1}$	$6.2 \times 10^{-2}$
3	14	2.0	0.5	6.6	$1.8 \times 10^{-3}$	$6.6 \pm 6.1 \times 10^{-3}$	$1.8 \times 10^{-3}$	$5.42 \times 10^{-2}$	$7.1 \times 10^{-2}$
4	14	2.0	1.5	3.9	$1.8 \times 10^{-3}$	$3.9 \pm 3.6 \times 10^{-3}$	$1.8 \times 10^{-3}$	$5.94 \times 10^{-2}$	$6.5 \times 10^{-2}$
5	17	1.0	0.5	7.8	$1.7 \times 10^{-3}$	$7.8 \pm 7.3 \times 10^{-3}$	$1.7 \times 10^{-3}$	$2.60 \times 10^{-2}$	$6.2 \times 10^{-2}$
6	17	1.0	1.5	5.7	$1.3 \times 10^{-3}$	$5.7 \pm 6.0 \times 10^{-3}$	$1.3 \times 10^{-3}$	$2.13 \times 10^{-3}$	$6.1 \times 10^{-2}$
7	17	2.0	0.5	7.4	$2.2 \times 10^{-3}$	$7.4 \pm 6.6 \times 10^{-3}$	$2.2 \times 10^{-3}$	$6.03 \times 10^{-2}$	$7.0 \times 10^{-2}$
8	17	2.0	1.5	4.4	$2.0 \times 10^{-3}$	$4.4 \pm 4.0 \times 10^{-3}$	$2.0 \times 10^{-3}$	$6.59 \times 10^{-2}$	$6.2 \times 10^{-2}$
9	20	1.0	0.5	8.7	$1.9 \times 10^{-3}$	$8.7 \pm 8.1 \times 10^{-3}$	$1.9 \times 10^{-3}$	$3.26 \times 10^{-2}$	$6.1 \times 10^{-2}$
10	20	1.0	1.5	6.6	$1.5 \times 10^{-3}$	$6.6 \pm 7.0 \times 10^{-3}$	$1.5 \times 10^{-3}$	$1.14 \times 10^{-1}$	$6.2 \times 10^{-2}$
11	20	2.0	0.5	8.1	$2.6 \times 10^{-3}$	$8.1 \pm 7.1 \times 10^{-3}$	$2.6 \times 10^{-3}$	$2.74 \times 10^{-2}$	$7.0 \times 10^{-2}$
12	20	2.0	1.5	4.8	$2.3 \times 10^{-3}$	$4.8 \pm 4.4 \times 10^{-3}$	$2.3 \times 10^{-3}$	$3.60 \times 10^{-2}$	$6.1 \times 10^{-2}$

## CONCLUSION

In this study, we propose an analytical model-based solution procedure to estimate the mean travel time of lifts and shuttles as well as mean amount of energy consumption per transaction in SBS/RS design. By the analytical models provided in this study, a plant manager can evaluate different SBS/RS designs based on the number of tiers, velocity profiles and acceleration/deceleration values of lifts/shuttles and number of bays in the warehouse, promptly. The performance of the SBS/RS is evaluated in terms of mean travel

time of lifts and shuttles as well as mean amount of energy consumption per transaction. The developed analytical results are validated via the simulation results for several SBS/RS design scenarios. As a result, it is found that the proposed model produces quite accurate results, specifically less than 0.07% deviations from the simulation results.

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## **Session 7: Complexity, Risk and Uncertainty**

# OPTIMAL RETIREMENT AGE AND RELATED DATABASE FOR THE TRANSPORTATION INDUSTRY WORKERS

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## Abstract

In Slovenia the retirement age of drivers and other workers in logistics is being raised. However, many workers, especially drivers and workers in big warehouses are not able to work until they have reached the increased retirement age. This problem is decreasing social security of workers in logistics, increasing their anxiety regarding the future and influencing the quality and safety of logistic processes. The problem escalated in January 2017, when the new occupational pension scheme for transportation workers has entered into force. Unions are protesting to the new decreased contribution rate of employers, because no serious research has been done, how it will influence transportation workers' social security in the environment of increasing retirement age of public pension scheme which is the complementary scheme to this professional pension scheme. There is high risk that the consequences of the lower contribution rate stipulated in the new occupational pension scheme will force them to work longer even when their functional capacities will decline to the level which does not allow for safe performances of their transportation related jobs. These exposure to risk of individual activities in a supply chain can influence losses in total chain. Disruptions and lower quality performances in one activity cell of a supply chain can have a ripple effect throughout an entire chain. To solve this problem, we should put in place supplementary occupational pension schemes, in which higher retirement age will not affect the reliability of logistic activities in the individual activity cell and therefore will not affect the total logistic network. This article is introducing a model how to determine economically acceptable contribution rate to the occupational pension scheme regarding exposure to risk of total chain, that is based on extended MRP Theory. The needed data which will support decisions on required parameters of the pension scheme are listed. The model can be used as a basis for negotiations between employers and unions in this suddenly escalated conflict to keep the transportation and other logistic activities at the same level of quality.

**Keywords:** logistics, drivers, superannuation, supply chain, risk, decision model, quality of supply.

## INTRODUCTION

Fatigue is common cause of accidents among drivers of trucks, other lorries and company cars. According to European Commission (EC, 2017) it is a significant factor in some 20% of crashes involving heavy commercial vehicles. By ageing, older drivers and other workers in logistics are losing their functional capacities and therefore they are becoming tired earlier. The percentage of older professional drivers increases as the European population ages and the retirement age increases, therefore we can expect also increasing number of traffic accidents where the age cohort of drivers older than 55 will be involved.

Table 1: The ratio between number of crashes caused by drivers of age cohort and number of all employed men in each cohort

Age cohort	<25	25-34	35-44	45-54	>55
Accidents per number of all employed men (%)	0.50	0.28	0.23	0.26	0.54

Source: SURS, 2017: <http://www.stat.si/StatWeb/News/Index/5364>

For example, the number of traffic accidents caused by drivers of heavy vehicles in Slovenia, in 2015 was 1364. There were only 87 cases of accidents caused by drivers of heavy vehicles, who were younger than 25 years, 318 cases caused by drivers age 25-34, 317 cases caused by drivers of age 35-44, 323 cases caused by drivers of age 45-54 and 294 cases caused by older drivers although the number of drivers 55+ in structure of the age cohorts of drivers is lower than average. The ratio between number of these accidents and number of all employed men in cohorts is presented in Tab. 1. According to The Ageing Report 2015 (EC, 2015), in the beginning of this century, many new and old EU Member States had begun to implement pension reforms. Therefore, increasing Social Security's retirement age appears to be gaining political traction in EU. In the course of the transition of economies of new EU Member States, their pension systems endured severe financial pressure. Therefore, they expressed willingness to rise the retirement age. In general this would promote work at older ages, improve the solvency of social system's by shortening periods spent in retirement and reducing lifetime pension benefits of the oldest Europeans. It could, however, create hardship for professional drivers with decreasing functional capacities, unless early retirement occupational pension scheme is set up for transportation workers on the EU level. Therefore, there should be action on the EU level to prevent the social dumping among the member states, where the states without mandatory contributions to occupational pension scheme would become more competitive on the EU logistics market. During the reforms of pension systems in EU member states, the retirement age has risen from below 60 to 65 years, and is expected to increase to 70 years by 2060. Many EU member states have implemented the automatic adjustment mechanisms in their pension legislation where retirement age follows increase in life expectancy. Due to the prolonged working period, workers often become liabilities, rather than assets for their companies, before they are old enough to retire.

Historically, occupational pension schemes were originally developed in logistics in general, and by American Express mail business (1875) and Baltimore and Ohio Railroad Company (1884) in particular, to lower the anxiety of workers with the respect of how to finance their livelihood after they are no longer able to work. Superannuation schemes were organisational pension programs that were developed and financed by companies for the benefit of their employees. These schemes enabled the employees to retire and permitted the company to employ younger and more reliable workers. Today, with the raising of the retirement age and the prolongation of the working period, the real ability to work in certain industrial and logistical workplaces is not taken into account. In addition, the problem of anxiety regarding the ability of a worker to work until the new retirement age is rising. Therefore, the new pension schemes with higher retirement ages are not meeting the objectives that they were designed for. In some countries, retirement age could be reduced by early retirement occupational pension schemes, but in many countries, these opportunities have been abolished or minimised by the reforms that were made after 1990. Whereas, the increasing retirement age can contribute to the decreasing quality and quantity of logistic services as well as causing delays and uncertainties regarding whether the products will be safely delivered on time. The influence on the added value in the total supply chain is different in different workplaces. How this phenomenon appears in global supply chains will be modelled and presented.

## **MODELLING AND EVALUATION OF THE IMPACT OF RETIREMENT AGE ON THE ENTIRE SUPPLY CHAIN**

### **The production–distribution logistics network design**

Production–distribution logistics network models provide managers of logistics companies with an effective tool for decision making especially to evaluate the perturbations in lead time and other delays in the system. Typical nodes (activity cells) represent vendors of raw materials or components, manufacturing and warehousing facilities in the production part of a supply chain, distribution centers for semi-products and final items, warehouses and customers. Like in Bogataj et al (2011) we shall use the term "activity cell" for anyone of these nodes. Edges represent the infrastructure for flows between activity cells. The



long-term performance goals for this production–distribution logistics system suggest strategic decision making regarding partners, playing different roles in the supply chain. To develop a model for optimal strategic decisions on retirement age where perturbation of lead time often appears, we depart from MRP theory, developed by (Grubbström, 1996). The early retirement age, as determined in an occupational pension scheme, could decrease by increasing contributions from gross earnings  $c_{L,i}$  of workers on  $(1+\alpha)c_{L,i}$  in the nodes of the supply network and their gross earnings  $(1+\alpha)c_{L,i,j}$  on the routes from  $i$  to  $j$  as determined in the extra occupational pension schemes in amount of  $\alpha c_{L,i}$  and  $\alpha c_{L,i,j}$  respectively. Thus, if the labour cost would increase from  $c_{L,i}$  to  $c_{L,i}(1+\alpha_i)$ , or  $c_{L,i,j}(1+\alpha_{i,j})$  respectively, where  $\alpha_i c_{L,i}$  and  $c_{L,i,j}(1+\alpha_{i,j})$  are factored into the occupational pension scheme, the retirement age of a driver or other workers in logistics at the workplace  $i$  or on the roads (edges  $i \rightarrow j$ ) can be lowered, which could increase the quality and quantity of logistic activities as well as improve a timing of activities in the workplace and reduce the lead time in a supply chain. The benefit to the total supply chain when costs of perturbations in timing should be also considered, could be evaluated through Grubbström's MRP model using the NPV approach in frequency domain. As written in Grubbström et al., (2010): "Several often-used mathematical operations in the time domain are quite cumbersome to perform, such as multiple integrations, their corresponding operations in the frequency domain become simple algebraic manipulations. The one-to-one property for a wide range of time functions and their transforms ensures that the resulting transform is a unique counter-part of the corresponding time function". The proposed analysis is based on the extended *MRP theory*, based on the papers of Grubbström (1996), Grubbström et al. (2010) and later extended to the global supply chain by Bogataj et al. (2011), in which the location and transportation is also considered, including regional characteristics, such as the cost of labour. For evaluations of activities in such a chain, the Net Present Value (NPV) criterion function is used, as in Bogataj and Grubbström (2012, 2013).

We consider a *logistic system*, in which the components of process  $j$  need to be in place  $\tau_j$  time units before completion and sent from parent node  $i$  to  $j$  with an additional (transportation) time delay  $\tau_{ij}$  in advance. This process can be perturbed by reducing functional capacities of aging drivers and other workers. The input requirements are given as transforms in the *generalised transportation- production-distribution-input matrix*, which is denoted by  $\tilde{\mathbf{H}}(s)$ , and  $\tilde{\mathbf{G}}(s)$  is given the *generalised transportation- production-distribution-output matrix*. Thus, the requirements for the production - distribution plan  $\tilde{\mathbf{P}}(s)$  written as  $\tilde{\mathbf{H}}(s)\tilde{\mathbf{P}}(s)$  are specified in the frequency domain, where a manipulation with the time variable transformed to frequency domains is much easier

$$\tilde{\mathbf{H}}(s) = \begin{bmatrix} 0 & 0 & \cdots & 0 \\ h_{21}e^{s\tau_{21}} & 0 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ h_{n1}e^{s\tau_{n1}} & h_{n2}e^{s\tau_{n2}} & \cdots & 0 \end{bmatrix} \begin{bmatrix} e^{s\tau_1} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & e^{s\tau_n} \end{bmatrix}. \quad (1)$$

There are some places of activities  $i$  in the nodes or on the transportation road  $(i, j)$ , where workers work on an activity longer than necessary. This occurrence creates additional lead time in nodes:  $\Delta\tau_i$ , and on roads:  $\Delta\tau_{i,j}$  which should be evaluated in our paper if the total lead time in  $i - th$  place of logistic activities (or production) is equal to  $\tau_i^{lg} = \tau_i + \Delta\tau_i$ , while on the transportation roads is equal to  $\tau_{ij}^{tr} = \tau_{ij} + \Delta\tau_{ij}$  respectively. This increase can be evaluated in the space of the complex-valued functions by introduction of

the perturbed matrix  $\tilde{\mathbf{H}}'(s)$ , on the way that production-distribution according to the plan  $\tilde{\mathbf{P}}(s)$  is fulfilled, which would be written as follows:

$$\tilde{\mathbf{H}}'(s)\tilde{\mathbf{P}}(s) = \begin{bmatrix} 0 & 0 & \cdots & 0 \\ h_{2,1}e^{s(\tau_{2,1}+\Delta\tau_{2,1})} & 0 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ h_{n,1}e^{s(\tau_{n,1}+\Delta\tau_{n,1})} & h_{n,2}e^{s(\tau_{n,2}+\Delta\tau_{n,2})} & \cdots & 0 \end{bmatrix} \begin{bmatrix} e^{s(\tau_1+\Delta\tau_1)} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & e^{s(\tau_n+\Delta\tau_n)} \end{bmatrix} \tilde{\mathbf{P}}(s). \quad (2)$$

By introducing perturbed delays also in output matrix on the similar way in the logistics or production nodes:  $\delta_i^{\text{lg}} = \delta_i + \Delta\delta_i$  and on the roads:  $\delta_{ij}^{\text{tr}} = \delta_{ij} + \Delta\delta_{ij}$ , the net production-distribution activities in the nodes of such production-transportation system will conveniently be written:

$$\begin{aligned} & (\tilde{\mathbf{G}}'(s) - \tilde{\mathbf{H}}'(s))\tilde{\mathbf{P}}(s) = \\ & = \left( \begin{bmatrix} e^{-s\delta_1^{\text{lc}}} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & e^{-s\delta_n^{\text{lc}}} \end{bmatrix} \begin{bmatrix} 0 & 0 & 0 & \cdots & 0 \\ \vdots & \cdots & g_{kj}e^{-s\delta_{kj}^{\text{tr}}} & \vdots \\ 0 & \cdots & 0 \end{bmatrix} - \begin{bmatrix} 0 & 0 & 0 & \cdots & 0 \\ \cdots & \cdots & h_{ij}e^{s\tau_{ij}^{\text{tr}}} & \ddots & \vdots \\ h_{n1}e^{s\tau_{n1}^{\text{tr}}} & h_{n2}e^{s\tau_{n2}^{\text{tr}}} & \cdots & 0 \end{bmatrix} \begin{bmatrix} e^{s\tau_1^{\text{lc}}} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & e^{s\tau_n^{\text{lc}}} \end{bmatrix} \right) \tilde{\mathbf{P}}(s) \quad (3) \end{aligned}$$

We name  $\tilde{\mathbf{G}}'(s) - \tilde{\mathbf{H}}'(s)$  the perturbed *generalised technology matrix* of a supply chain (Bogataj et al, 2011) and  $\tilde{\mathbf{G}}(s) - \tilde{\mathbf{H}}(s)$  is the special, unperturbed *generalised technology matrix*. For simple demonstration of our method we shall write the net production and supply  $\tilde{\mathbf{x}}(s)$  for the simplified case where  $\mathbf{G}=\mathbf{I}$  as follows:

$$\begin{aligned} \tilde{\mathbf{x}}(s) &= \{\mathbf{I} - \tilde{\mathbf{H}}'(s)\}\tilde{\mathbf{P}}(s) = \\ &= \left\{ \mathbf{I} - \begin{bmatrix} 0 & 0 & \cdots & 0 \\ h_{2,1}e^{s(\tau_{2,1}+\Delta\tau_{2,1})} & 0 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ h_{n,1}e^{s(\tau_{n,1}+\Delta\tau_{n,1})} & h_{n,2}e^{s(\tau_{n,2}+\Delta\tau_{n,2})} & \cdots & 0 \end{bmatrix} \begin{bmatrix} e^{s(\tau_1+\Delta\tau_1)} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & e^{s(\tau_n+\Delta\tau_n)} \end{bmatrix} \right\} \tilde{\mathbf{P}}(s) \quad (4) \end{aligned}$$

### The economic consequences in the activity cells

For *cyclical processes*, which repeat themselves in constant time intervals  $\Gamma_j$ ,  $j = 1, 2, \dots, m$  where  $\Gamma_j$  could be also perturbed:  $\Gamma_j \rightarrow \Gamma_j + \Delta\Gamma_j$ , the plan  $\tilde{\mathbf{P}}(s)$  for the case when  $s$  is replaced with the continuous interest rate  $\rho$  is written as suggested by Grubbström and written in Bogataj et al (2011), here now also introduced by delays in the distributed starting moments  $\Delta t_i$  of a cycle and delays in cycles  $\Delta\Gamma_j$ :

$$\tilde{\mathbf{P}}'(\rho) = \tilde{\mathbf{t}}^p(\rho)\tilde{\mathbf{\Gamma}}^p(\rho)\hat{\mathbf{P}} \square \frac{1}{\rho} \left[ \frac{e^{-\rho(t_1+\Delta t_1)}\hat{P}_1}{\Gamma_1 + \Delta\Gamma_1} \quad \cdots \quad \frac{e^{-\rho(t_n+\Delta t_n)}\hat{P}_n}{\Gamma_n + \Delta\Gamma_n} \right]^T. \quad (5)$$

Here  $T$  means the transposed vector.  $\hat{\mathbf{P}}$  is a vector of constants: for instance,  $\hat{\mathbf{P}}$  could describe the total amounts (batch sizes) to be produced or transported, or delivered by

each process during one of the periods. Furthermore, in the equation (5) where  $t_j, j = 1, 2, \dots, n$ , are the points in time when the first of each respective cycle starts in  $j$ -th activity cell or from the cell to the child node. Please refer to the details in Grubbström et al. (2010), who developed Eq. (5) without delays for small continuous interest rates  $\rho = s \ll \Gamma_j$ .

The Net Present Value (NPV) principle as a basic principle for economic evaluation of systems and their control, was previously used in the actuarial science, now also in the risk theory in general. This approach has been applied in many production-inventory problems, for example, Hadley, 1964; Teunter and van der Laan, 2002, and recently Chen, 2012. We collect the economic values of items into a price vector  $\mathbf{p}$  which is a row vector, as follows:

$$\mathbf{p} = [p_1, p_2, \dots, p_n]. \quad (6)$$

In general, each activity cell produces or workers manipulate in warehouses and other logistic platforms with items. Therefore, for a certain production or distribution activities at a certain stage of a supply chain, we can assume

$$\mathbf{p} = \mathbf{p} + \Delta \mathbf{p} = [p_1(1 + \delta_1^p), p_2(1 + \delta_2^p), \dots, p_n(1 + \delta_n^p)], \quad (7)$$

where  $\delta_i^p$  is the relative reduction of prices of item  $i$  ( $\delta_i^p \leq 0$ ), because the worker in production or logistic unit  $i$  is no longer able to assure the best quality of products, due to his advanced age. We can expect that the majority of places have set these values equal to 0, but in some workplaces, this reduction of value could appear because decreasing functional capacities of workers. In such a system the NPV of the cash flow is obtained by substituting the complex frequency  $s$  for the continuous interest rate  $\rho$ . When the general economic growth  $e^{\omega t}$  is considered due to the increasing productivity and improvements of supply chains, we write the annuity streams as:

$$\text{NPV} = \sum_{i=1}^n \left\{ p_i(1 + \delta_i^p) \tilde{x}_i(\rho - \omega) - K_i e^{-(\rho - \omega)(t_i + \Delta t_i)} \hat{P}_i / [(\rho - \omega)T_i] \right\}. \quad (8)$$

where  $\mathbf{K} = \{K_1, K_2, \dots, K_n\}$  is the vector of ordering/setup and fixed production or logistics costs per cycle appearing in the nodes (also at arrival and/or departure of cargo). From (3) having perturbed timing and economic growth  $e^{\omega t}$  we can write:

$$\tilde{\mathbf{x}}(\rho - \omega) = \left\{ \begin{bmatrix} 1 & 0 & \dots & 0 \\ -h_{2,1}e^{(\rho - \omega)(\tau_{2,1} + \Delta \tau_{2,1})} & 1 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ -h_{n,1}e^{(\rho - \omega)(\tau_{n,1} + \Delta \tau_{n,1})} & -h_{n,2}e^{(\rho - \omega)(\tau_{n,2} + \Delta \tau_{n,2})} & \dots & 1 \end{bmatrix} \begin{bmatrix} e^{(\rho - \omega)(\tau_1 + \Delta \tau_1)} & \dots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \dots & e^{(\rho - \omega)(\tau_n + \Delta \tau_n)} \end{bmatrix} \right\}. \quad (9)$$

$$\cdot \begin{bmatrix} e^{-(\rho - \omega)(t_1 + \Delta t_1)} & \dots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \dots & e^{-(\rho - \omega)(t_n + \Delta t_n)} \end{bmatrix} \begin{bmatrix} \hat{P}_1 & \dots & \hat{P}_n \\ (\rho - \omega)\Gamma_1 & \dots & (\rho - \omega)\Gamma_n \end{bmatrix}$$

Here we introduced the effect of aging due to a higher retirement age and its impact on NPV. The aging effects is translated into financial consequences by lower prices for  $\delta p_i = p_i \delta_i^p$ , delayed moments of starting in timing of the first cycles of activities in the nodes  $i: \Delta t_i$ , longer time of transportation  $\Delta \tau_{i,j}$  on the edges and manipulation  $\Delta \tau_i$  detected in the nodes, expressed in  $\tilde{\mathbf{x}}(\rho - \omega)$  and calculated by equation (3) where the growth of economy  $e^{\omega t}$  is assumed. We also need to take the direct costs of labour into

account. The total  $NPV$  ( $NPV_{total}$ ) should be reduced for the  $NPV$  of payments with respect to the labour in individual places of activity with activities in the nodes  $P_i$  and activities on the routes. The results in the nodes could be written as  $c_i L_i P_i$ , where  $c_i$  is the cost of one unit of work, which also includes the part of gross earnings that is sent to the occupational pension fund, and  $L_i$  is number of workers, which needed for the production or distribution of one unit of item  $i$ , but the financial results of delays are hidden in (2), (4) and (5).

### Transportation costs

Between location of activity cell  $i$  and child node, activity cell  $j$ , transportation costs per item in transport could be determined by the product  $(b_{ij} + c_{ij})\tau_{ij}$  where  $b_{ij}$  presents transportation costs of vehicle per item per time unit and  $c_{i,j}$  presents transportation costs of driver and other workers in logistics if involved on the edge  $i \rightarrow j$  which we collect into a transportation price matrix so that transportation costs between activity cells are equal to:  $\mathbf{E}^T \tilde{\mathbf{P}}'_H(\rho) \tilde{\mathbf{P}}'(\rho) =$

$$= \begin{bmatrix} 0 & \dots & \dots & \dots & \dots & 0 \\ h_{21}(b'_{21} + c_{21})(\tau_{21} + \Delta\tau_{21}) & \dots & \dots & \dots & \dots & 0 \\ \dots & h_{ij}(b'_{ij} + c_{ij})(\tau_{ij} + \Delta\tau_{ij}) & \dots & \dots & \dots & 0 \\ \dots & \dots & \dots & \dots & \dots & 0 \\ h_{n1}(b'_{n1} + c_{n1})(\tau_{n1} + \Delta\tau_{n1}) & h_{nj}(b'_{nj} + c_{nj})(\tau_{nj} + \Delta\tau_{nj}) & \dots & \dots & \dots & 0 \end{bmatrix} \begin{bmatrix} e^{\rho(\tau_1 + \Delta\tau_1)} & \dots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \dots & e^{\rho(\tau_n + \Delta\tau_n)} \end{bmatrix} \tilde{\mathbf{P}}(\rho) \quad (9)$$

We can write:  $c_{ij} = (1 + \alpha)c_{ij}^0$ , where  $\alpha$  is the share of the cost of labour that is allocated through an employer contribution to either the pension fund or the occupational pension scheme and  $c_{ij}^0$  is the previous salary without the part being paid for early retirement. We need to write the NPV of the cost of labour so that it includes the cost of early retirement. Therefore the NPV of difference of the cost of labour in nodes and on the transportation road due to the contributions to the special occupational pension fund is:

$$\Delta NPV_{wages} = \sum_{j=1}^n \left\{ \alpha_j c_j^0 L_i + \sum_{i=2}^n \alpha_{ij} c_{ij}^0 h_{ij}(\tau_{ij} + \Delta\tau_{ij}) \right\} \frac{e^{-(\rho-\omega)t_i} P_i}{(\rho-\omega)\Gamma_i}. \quad (10)$$

This amount should be lower than the NPV of difference between unperturbed and perturbed logistic activities in the supply chain as could be written:

$$(\rho - \omega) \Delta NPV_{wages} \leq \left\{ \mathbf{p}(\mathbf{I} - \tilde{\mathbf{H}}(\rho - \omega)) - \mathbf{K} \right\} \begin{bmatrix} \frac{e^{-(\rho-\omega)t_1} \hat{P}_1}{\Gamma_1} \\ \vdots \\ \frac{e^{-(\rho-\omega)t_n} \hat{P}_n}{\Gamma_n} \end{bmatrix} - \left\{ (\mathbf{p} + \Delta\mathbf{p})(\mathbf{I} - \tilde{\mathbf{H}}'(\rho - \omega)) - \mathbf{K} \right\} \begin{bmatrix} \frac{e^{-(\rho-\omega)(t_1 + \Delta t_1)} \hat{P}_1}{\Gamma_1 + \Delta\Gamma_1} \\ \vdots \\ \frac{e^{-(\rho-\omega)(t_n + \Delta t_n)} \hat{P}_n}{\Gamma_n + \Delta\Gamma_n} \end{bmatrix} \quad (11)$$

### THE NUMERICAL EXAMPLE

Let us assume a graph of assembly system where the nodes are in different regions therefore the transportation time is significantly long. We assume  $\Gamma = 68h = 7.76 \cdot 10^{-3}$  years;  $\Delta\Gamma = 9h = 10^{-3}$  years. Let us also assume that the old drivers between 60 and 69 in their last decade of driving before retire, influence lead time on the roads between the nodes. Their functional capacities have fallen so that the time on the roads is 20% longer than if they would be younger. Also expected insurance costs for traffic accidents are rising transportation costs for 2%:  $b'_{ij} = 1.02 \cdot b_{ij}$ . There are no logistic problems with delays inside the nodes, but there are problems with quality of products. The product structure of graph is given in Figure 1. According to Figure 1, there are five different activities and semi-products or products (items). Activity B represents the assembly of 2 units of item D and 1 unit of item E, activity A requires 2 units of C and hundred units of B for the production of one unit of A. At  $\rho = 0.03$  and production growth  $\omega = 0.01$ , at reduced quality for  $\Delta p = -0.15p$ , we need to have the following data from logistics database:

$$\Gamma_i + \Delta\Gamma_i = 8.76 \cdot 10^{-3} \text{ years}; c_{ij}^0 = 30\text{€}/h \quad \forall i, j; b'_{ij} = 153\text{€} \quad b_{ij} = 150\text{€}/h; \quad \forall (i, j);$$

$$(\rho - \omega) / 365 \cdot 24 = 1 / (4.38 \cdot 10^3); \quad t_1 = 62h; t_2 = 34h; t_3 = 42h; t_4 = 8h; t_5 = 1h$$

$$\mathbf{K} = \begin{bmatrix} 100 & 12 & 20 & 9 & 5 \end{bmatrix}; \quad \mathbf{p} = 10^3 \cdot \begin{bmatrix} 600 & 102 & 90 & 0.6 & 1.2 \end{bmatrix};$$

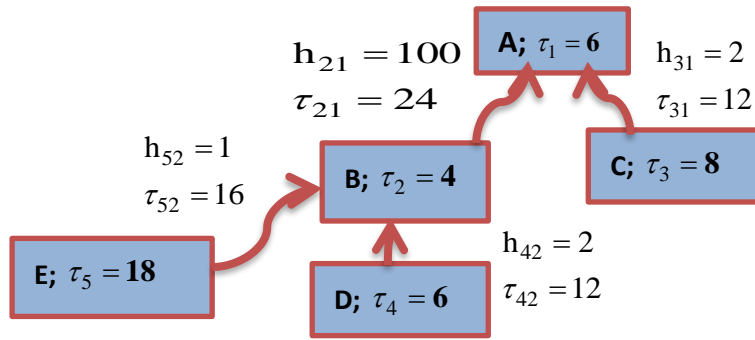


Figure 1: An example of a supply chain structure of an assembly system

$$\mathbf{I} - \tilde{\mathbf{H}}' = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ -100e^{\frac{1.2 \cdot 24 + 6}{4.38 \cdot 10^3}} & 1 & 0 & 0 & 0 \\ -2e^{\frac{1.2 \cdot 12 + 6}{4.38 \cdot 10^3}} & 0 & 1 & 0 & 0 \\ 0 & -2e^{\frac{1.2 \cdot 12 + 4}{4.38 \cdot 10^3}} & 0 & 1 & 0 \\ 0 & -e^{\frac{1.2 \cdot 12 + 4}{4.38 \cdot 10^3}} & 0 & 0 & 1 \end{bmatrix}; \tilde{\mathbf{P}}' = \frac{1}{8.76 \cdot 10^{-3} \cdot 2} \begin{bmatrix} \frac{-1.2 \cdot 62}{4.38 \cdot 10^3} \\ 11e^{\frac{-1.2 \cdot 62}{4.38 \cdot 10^3}} \\ \frac{-1.2 \cdot 34}{4.38 \cdot 10^3} \\ 1150e^{\frac{-1.2 \cdot 34}{4.38 \cdot 10^3}} \\ \frac{-1.2 \cdot 42}{4.38 \cdot 10^3} \\ 22e^{\frac{-1.2 \cdot 42}{4.38 \cdot 10^3}} \\ \frac{-1.2 \cdot 8}{4.38 \cdot 10^3} \\ 1109e^{\frac{-1.2 \cdot 8}{4.38 \cdot 10^3}} \\ \frac{-1.2}{4.38 \cdot 10^3} \\ 2300e^{\frac{-1.2}{4.38 \cdot 10^3}} \end{bmatrix}$$

$$[\mathbf{p}' \cdot (\mathbf{I} - \tilde{\mathbf{H}}') - \mathbf{K}] \cdot \tilde{\mathbf{P}}' = (1.0701\text{€} - 0.0022) \cdot 10^9\text{€} = 1.0679 \cdot 10^9\text{€};$$

$$[\mathbf{p}' \cdot (\mathbf{I} - \tilde{\mathbf{H}}) - \mathbf{K}] \cdot \tilde{\mathbf{P}} = 1.2660 \cdot 10^9\text{€} - 0.0024 \cdot 10^9\text{€} = 1.2636 \cdot 10^9\text{€}. \quad \text{The NPV would increase for 18.3\%}.$$

From equation (9), where  $b'_{ij} + c_{ij} = 150 \cdot 1.02 + 30$ , we have got  $\mathbf{E}^T \tilde{\Pi}'_H(\rho) \tilde{\mathbf{P}}'(\rho) = 0.8884 \cdot 10^9 \text{€}$  but for unperturbed systems where  $b_{ij} + c_{ij}(1 + \alpha) = 150 + 30(1 + \alpha)$ , we got:  $\mathbf{E}^T \tilde{\Pi}_H(\rho) \tilde{\mathbf{P}}(\rho) = 4345533(180 + 30\alpha) = (0.7822 + 0.1304\alpha) \cdot 10^9 \text{€}$ . From here it follows:  $1.0679 - 0.8884 = -(0.7822 + 0.1304\alpha) + 1.2636 \Rightarrow \alpha = 0.3019 / 0.1304 = 2.3$ . Because  $\alpha \geq 1$  it is better to employ younger driver, allow the older driver to retire and pay him the last decade pension equal to salary.

## CONCLUSIONS

In this paper, we have illustrated how to use extensions of MRP theory in the total supply chain (EMRP) for the purposes of planning the retirement age of drivers and other workers in logistics. Longevity of population in the EU is rising, therefore retirement ages in the national pension schemes of EU countries are also rising, with the aim of sustainable pension system. However, many drivers and other workers in logistics are not able to work until they reach the newly determined retirement age, that will approach 70 years by 2060. This problem is decreasing the social security of drivers and other workers in logistics, and influencing their safety on the roads as well as additional delays of the lead times between two logistics nodes. It has also negative impact on quality of production and distribution processes. We have derived the model for trade-off between quality of logistic processes and additional contributions to occupational pension schemes for early retirement of drivers and other workers in logistics. The numerical example shows that it is often better to allow a driver to retire and pay him the pension, as high as salary and employ a new driver. From the method presented here we can create a list of data needed for NPV evaluation. They should be a part of the supply chain information system, to be able to evaluate the economics of decision regarding such replacements.

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# DATA DRIVEN NETWORK ANALYSIS FOR IMPROVED SUPPLY CHAIN RISK MANAGEMENT

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## ABSTRACT

### Purpose

The intensified off-shoring and outsourcing of manufacturing in recent decades has transformed supply chains dramatically. Besides geographical dispersion, increasing fragmentation of manufacturing has made it difficult to determine exactly where and by whom many components or even final products are made. Both, global dispersion and fragmentation, have led to extremely complex and vulnerable supply chain networks. In such complex networks, supply chain disruptions, which are referred to as combinations of (1) an unintended anomalous triggering event materializing somewhere in the supply chain or its environment and (2) a consequential situation which significantly threatens normal business operations, become more likely and may lead to a breakdown of the entire network structure with significant operational and financial risks on the companies directly involved and the entire network of organizations.

### Design

The provided analysis is built upon extensive supply network data derived from Bloomberg Supply Chain (SPLC). The data set provides the business relationships a lead firm and its suppliers in terms of the flow of sales and in some cases, the amount of business, which can be interpreted as tie strength. Using social network analysis (SNA), we are investigating the application of public network data in improving supply chain visibility which is considered as an important element in supply chain risk mitigation. In addition, we study how differences in the identified network topology would moderate the impact and likelihood of disruption.

### Findings

It is shown that using social network analysis for public network data may create end-to-end supply chain visibility to enable risk mitigation. In addition, the likelihood and impact of potential supply chain disruptions is highly dependent on network topology which allows a more efficient management of supply chain risks.

### Value

Although supply chain disruptions and the management of supply chain risks have frequently been considered in the literature, data-driven approaches creating end-to-end supply chain visibility based on publicly available information and by thus allowing a more efficient management of supply chain risks are scarce. The main contribution of this research is as follows. To our best knowledge, there are no studies looked into data-driven approaches for supply chain risk management in a real network setting. Unlike to the previous papers of similar nature where simulated networks were used, we use a real network data from Bloomberg SPLC to improve visibility and uncover risks.

## INTRODUCTION

The intensified off-shoring and outsourcing of manufacturing in recent decades has transformed supply chains dramatically. Besides geographical dispersion, increasing fragmentation of manufacturing has made it difficult to determine exactly where and by whom many components or even final products are made. Both, global dispersion and fragmentation, have led to extremely complex networks (Brennan et al., 2015). Simultaneously, supply chain virtuality, i.e. the extent to which a company relies on its supply chain for manufacturing products, is increasing which is again supposed to increase the need for visibility as companies are losing direct control on their supply chain (Caridi et al., 2010).

In such complex and virtual networks, supply network disruptions, which are referred to as combinations of (1) an unintended anomalous triggering event materialising somewhere in the supply chain or its environment and (2) a consequential situation which significantly threatens normal business operations (Wagner and Bode, 2008), become more likely to occur. According to the report by the Business Continuity Institute, 85% of companies reported at least one supply network disruption in the last 12 months (Marley et al., 2014). Moreover, as shown in several empirical studies, those supply network disruptions impose significant operational and financial risks on the companies directly involved and the entire network of organizations (Hendricks and Singhal, 2005a; Hendricks and Singhal, 2005b) and can be devastating to the profitability and productivity of those companies (Marley et al., 2014). Due to the inter-connected nature of supply networks, the disruption in one node may also impact not only the node itself but other connected nodes as well (Shin et al., 2012; Han and Shin, 2016). This may even induce cascading effects that emanate from interlinkages and interdependencies within the network. An effective management of supply chain risks therefore requires the evaluation of the likelihood and degree of negative consequences to the larger network based on the fact that the failure of a single entity or cluster of entities can cause a cascading failure, which could finally damage or potentially bring down an entire network (Helbling, 2013). Those cascading risks of collapsing network nodes or network links threatening the entire network have not received sufficient academic attention so far in the context of supply chain risk management (SCRM) (e.g., Craighead et al., 2007) and will therefore be subject of the present paper.

Supply chain risks cascading through a network of organisations are highly dependent of the structural characteristics of the supply network that would influence (1) speed of propagation and (2) severity of a disruption for connected nodes as well as the entire network. In order to tackle this issue, it is necessary to increase confidence in the supply chain by improving visibility and control (Christopher and Lee, 2004). Total end-to-end visibility will allow supply chains to be more transparent, facilitating the flow of information throughout the network of organisations. Enabling adequate control levers to be accessible to the partners which is required for prompt actions to be taken when necessary. In the following, we present a data-driven approach supporting end-to-end supply chain visibility based on publicly available information aiming at a more efficient management of supply chain risks. Using real-life supply network data from 119 electronics companies, we seek to investigate the structural characteristics of supply chains and the implications for their risk exposure. The next sections introduce and review relevant concepts from the literature whereas Section 3 describes the methodological background for social network analysis based on the example of the electronics industry. Section 4 concludes the article and provides some preliminary findings.

## LITERATURE REVIEW

A network refers to "a set of nodes and the set of ties representing some relationships, or lack of relationships, between the nodes", (Brass et al., 2004). Various types of business networks have been analysed based on the idea that actors in a network influence each other via transmission mechanism such as information flow rather than being independent (Borgatti and Li, 2009). The main focus of investigating a business network was on gaining understanding how a firm's position in a network would facilitate its access to knowledge and resources held by the others in the network (Uzzi, 1996; Wasko and Faraj, 2005; Carter et al., 2007; Greve, 2009; Capó-Vicedo et al., 2011).



A supply network is a good example of a network, characterised by interactions and dependencies among different actors, resources and processes (Surana et al., 2005; Borgatti and Li, 2009; Hearnshaw and Wilson, 2013; Bellamy et al., 2014). In a supply network, the links between companies can be a material/information flow (Chopra and Sodhi, 2004; Kim et al., 2011), as well as a contractual relationship (Kim et al., 2011). A supply network is an important source of competitiveness for the buyers such as knowledge, innovation and operational efficiency (Uzzi, 1996; Corbett et al., 1999; Dyer and Nobeoka, 2000; Greve, 2009; Bellamy et al., 2014; Gao et al., 2015).

One main characteristic of a supply network is the existence of "hub-firm". Hub-firm refers to a main buying firm that sets up the network and manages it (Jarillo, 1988) and it often has power over other companies in the network due to (1) its central location (Wilhelm, 2011) and (2) its ability to bridge a structural whole (Burt, 1995). In addition, these hub-firms tend to rely on a limited number of core suppliers for components and knowledge (Dedrick et al., 2010). Another characteristic is that a supply network has relatively high level of stability, since it is built upon repeated transactions between a buying firm and its suppliers (Wilhelm, 2011).

A typical modern supply network is made up of complex inter-connections between different types of companies such as suppliers, manufacturers and retailers (Pathak et al., 2007). For this reason, viewing a supply network as a collection of sequential dyadic relationship would over-simplify and distort the realities of a modern supply network (Hearnshaw and Wilson, 2013). Indeed, there is a growing call to expand the traditional dyadic perspective of SCM research into the network perspective (Choi et al., 2001; Pathak et al., 2007; Borgatti and Li, 2009; Kim, et al., 2011; Bellamy et al., 2014). A SCM research from the network view, however, is still relatively rare. The main reason for this is the difficulty in obtaining a real-life supply network data, therefore, the majority of such studies analysed firm level ego networks (e.g., Choi and Hong, 2002; Kim et al., 2011). There is a small but growing number of studies using an industry-level supply network data, for examples, see Basole (2009), Greve (2009), and Bellamy et al., (2014).

### **Social network theory and embeddedness of a firm**

The theoretical lens used for this paper is social network theory. The social network theory is based on the idea of embeddedness (Kim, 2014). Early thoughts on motivations for economic actions were complementarity and utility of such actions (Barden and Mitchell, 2007; Cowan et al., 2007). However, some scholars started to argue that complementarity and utility may not be an only determinant for an economic exchange and there are non-economic factors influencing such activities (Moran, 2005; Barden and Mitchell, 2007; Cowan et al., 2007; Landoli et al., 2012; Vinhas et al., 2012; Kim, 2014). Such factors are referred as "embeddedness" (Kim, 2014). One notable example of embeddedness is "a social tie" which is known to shape the economic exchanges (Koufteros et al., 2007; Dong et al., 2015), since exchange activities are often embedded in them.

The link between firms' performance and embeddedness in an economic exchange have been scrutinised by the scholars (1) to find how the embeddedness would influence the way a firm behaves in an economic exchange (Uzzi, 1996; Kim, 2014) and (2) to explain how different levels of embeddedness are related to the variations in firms' performance (Adler and Kwon, 2002; Kim, 2014). As such, social capital theory postulates embeddedness in a relationship as a capital (Koka and Prescott, 2002; Lawson et al., 2008), which is regard as valuable and non-imitable resources (Nahapiet and Ghoshal, 1998) for firm's competitiveness (Rowley et al., 2000; Son et al., 2016).

Firm's embeddedness have been investigated from two distinctive perspectives, which are (1) configurations of social ties and (2) quality of social ties, (Gulati, 1998; Uzzi and Lancaster, 2003; Moran; 2005; Autry and Griffis, 2008; Dong et al., 2015; Kim and Henderson, 2015). This reflects that an economic exchange and its outcomes are influenced by a firm's dyadic relationship as well as the broad structure of its network (Hagedoorn, 2006). As such, even though there are some variations of conceptualisation of the embeddedness (Tsai and Ghoshal, 1998; Min et al., 2008; Kim, 2014), two salient forms of embeddedness are (1) relational and (2) structural (Granovetter, 1985, 1992; Uzzi, 1996, 1997; Gulati, 1998; Rowley et al., 2000).

Relational embeddedness refers to the strength of dyadic ties (Granovetter, 1992; Moran, 2005; Kim, 2014) that is an extent to which a firm develops close and personal relationships with other members in its network (Barden and Mitchell, 2007; Autry and Griffis, 2008; Landoli et al., 2012; Dong et al., 2015). Relational embeddedness is created and leveraged during the history of interactions between actors (Granovetter, 1992), and is a multi-dimensional concept (Nahapiet and Ghoshal, 1998) including trust (Putnam, 1995), benevolence (Carey et al., 2011), commitment (Coleman, 1994) and obligation (Granovetter, 1992; Coleman, 1994).

Structural embeddedness, which is the main focus of the investigation of this paper, refers to impersonal configuration of linkages/relationships among actors (Nahapiet and Ghoshal, 1998; Gulati and Gargiulo, 1999; Moran, 2005; Barden and Mitchell, 2007; Dong et al., 2015). While, relational embeddedness is at dyadic and personal level, structural embeddedness is at impersonal and network level (Nahapiet and Ghoshal, 1998; Barden and Mitchell, 2007; Autry and Griffis, 2008; Landoli et al., 2012; Dong et al., 2015). Structural embeddedness provide a firm with access to resources (Nahapiet and Ghoshal, 1998; Kim, 2014) and information (Nahapiet and Ghoshal, 1998; Cowan et al., 2007) from its imminent partners and beyond.

### **Structural embeddedness and supply network disruption**

Prior research (Bode and Wagner, 2015; Kim, et al., 2015; Han and Shin, 2016) has suggested that structural embeddedness of a network would have impact on various aspect of SCRM such as the level of risk exposure, modes of responding, firm's capability to respond. SCRM research from the network perspective has investigated the place of structural embeddedness in SCRM from two rather contradicting perspectives (Kim et al., 2015).

The first view argues that a certain structural characteristics of a supply network (structural embeddedness) is positively related to its likelihood of withstanding a supply network disruption (Hearnshaw and Wilson, 2013; Kim et al., 2015; Han and Shin, 2016) as well as its capability to respond (Lomi and Pattison, 2006; Jüttner and Maklan, 2011). Scholars subscribing this view tend to define a supply network disruption as the loss of a walk between the nodes (e.g., suppliers) and a sink node (e.g., a final assembler) due to the removal of other node(s) and/or arc(s) (e.g., supplier site shut down due to a fire and/or a severed transport link due to a bad weather), (Kim et al., 2015). Then, network resilience (its likelihood of survival) can be defined as the extent to which a network stays connected at removal of node(s) and arc(s) (Albert et al., 2000; Hearnshaw and Wilson, 2013; Kim, et al., 2015; Han and Shin, 2016).

Considering the above, a network with a high level of centralisation is related to the high probability of a network survival (Hearnshaw and Wilson, 2013; Kim et al., 2015). For example, scale-free networks are more resilience to random disturbance (Albert et al., 2000; Hearnshaw and Wilson, 2013; Kim et al., 2015) since such disturbance would more likely to attack one of many peripheral nodes. This means, on the other hand, such networks are vulnerable to targeted attacks on the lead nodes (Albert et al., 2000; Hearnshaw and Wilson, 2013), suggesting that fitness of a hub-firm will determine resilience of the supply network (Hearnshaw and Wilson, 2013).

Another argument on the positive link between the network resilience and high level of centrality is based on the idea of redundancy. Firms tend to secure resource flows by creating redundancy in its supply network, maintaining a certain connections without imminent values (Uzzi, 1996; Sheffi and Rice, 2005; Lomi and Pattison, 2006). For example, a firm with multiple suppliers (high level of degree centrality) may deal an inbound disruption better than those with fewer suppliers. This is because if nodes (suppliers) on the same level could be replaceable, then wider horizontal connections at the supplier layers (e.g., in degree centrality) would reduce the impact of disruptions (Han and Shin, 2016).

The second view argues that a certain structural characteristics of a supply network (structural embeddedness) is a cause of a supply network disruption (Borgatti and Li, 2009; Bode and Wagner, 2015; Kim et al., 2015). This view is based on the idea of network structural complexity (Kim et al., 2015). Network complexity refers to the number and

variety of elements defining the system (Bode and Wagner, 2015). From SCA perspective, at the node level, network complexity is related to degree centrality, which refers to the number of its direct suppliers and customers (Borgatti and Li, 2009; Kim et al., 2011; Kim et al., 2015). At the network level, network complexity can be measured by two network metrics, which are network density and centralisation. Network density in a supply network means the overall level of connectedness among organisations in the network (Autry and Griffis, 2008; Kim et al., 2011), while network centralization refers to the extent to one of a few organisations (such final assemblers) are considerably more centrally connected than others (Kim et al., 2011).

Bode and Wagner (2015) argued that network complexity is related to the occurrence of a disruption in two ways. Firstly, as the number of the companies in a network increases (more complexity in the network), the likelihood of a disruption occurrence also increases (Perrow, 1984; Bode and Wagner, 2015). Secondly, as a network becomes more complex, a firm's ability to mitigate and response a supply network disruption would decrease (Bode and Wagner, 2015) due to the high level of operational burdens related to the complexity (Borgatti and Li, 2009; Kim et al., 2011; Kim et al., 2015). For example, high-level of degree centrality may imply that a focal firm's SCRM requires significance resources since it requires extensive co-ordination with its tier 1 suppliers. At the network level, SCRM in a dense supply network can be difficult due to the difficulty in sense-making. In other words, a less complex supply chain (e.g., short average path length) would enable firms respond more quickly to a disruption (Nair and Vidal, 2011).

## **METHODOLOGY AND EXAMPLE**

Social network analysis is relatively new in the field of SCM (Carter, 2007) and its initial slow adaptation was due to the lack of a clear idea on how SNA metrics can be translated for a supply network (Kim, et al., 2011). Nevertheless, it is becoming a popular theoretical and methodological lens for SCM research from the network perspective (Brogatti and Li, 2009; Kim, et al., 2011) and has helped scholars to better understand how supply network characteristics are translated into competitive advantages of a firm (e.g., Capó-Vicedo et al., 2011; Kim, et al., 2011, Bellamy et al., 2014; Kim et al., 2015). From SNA perspective, structural embeddedness of a network can be measured using network metrics (Kim et al., 2015). Network metrics consist of (1) node level and (2) network level metrics (Powell et al., 2005; Kim et al., 2011). Node centrality has three major dimensions, which are degree, closeness, and betweenness centrality (Everett and Borgatti, 1999; Provan et al., 2007; Borgatti and Li, 2009; Kim et al., 2011). Network-level metrics are related to structure of an overall network (Powell et al., 2005; Kim et al., 2011). Network-level metrics are useful when comparing network level characteristics (e.g., network level absorptive capacity) with other networks or over time (Provan, et al., 2007). There are two major network-level metrics, which are network density and network centralisation (Provan et al., 2007; Kim, et al., 2011). The methodological approach for studying supply networks either (1) analyse hypothetical supply networks using mainly simulation (Kim, 2009; Pathak, et al., 2007; Kim, et al., 2015) or (2) investigate real-networks using empirical methods (Jarillo and Stevenson, 1991; Choi and Hong, 2002; Kim, et al., 2011, Bellamy et al., 2014).

In this paper, we investigate structural embeddedness of electronics companies. The electronics industry was selected for the investigation for the following reasons. The electronics industry is characterised with high-level of uncertainty, short product life cycle and high level of globalisation, which are closely related to supply network disruptions (Sodhi and Lee, 2007). The required supply network data collected in the following manner. Firstly, a list of the companies was built using "Forbes Global 2000: The World's Biggest Companies, 2016". The Forbes Global 2000 lists the world's largest public companies based on an index that takes into account four different variables: revenues, profits, assets and market value (Forbes, 2016). We chose to have companies from the sectors made up of the global electronics industry, which are (1) communications equipment, (2) business products and supplies, (3) computer hardware, (4) computer storage devices, (5) consumer electronics, electronics, (6) household appliances, (7) security system, and (8) semiconductors. This resulted in 119 lead companies.

Secondly, supplier and customer data was collected for each lead firm using Bloomberg SPLC database. Bloomberg SPLC database provides supply chain relationships data (key suppliers, customers and competitors) on 26,000 companies retrieved from different sources such as financial documents, news releases and company presentations (Bloomberg, 2016). Our final data set contains 17,201 companies (including 119 lead firms). The collected data was then used to form the adjacency matrix to conduct a social network analysis. Finally, the adjacency matrix was imported into the UCINET 6.620 software that is commonly used for social network analysis (Borgatti et al., 2002) to calculate the node and network level metrics.

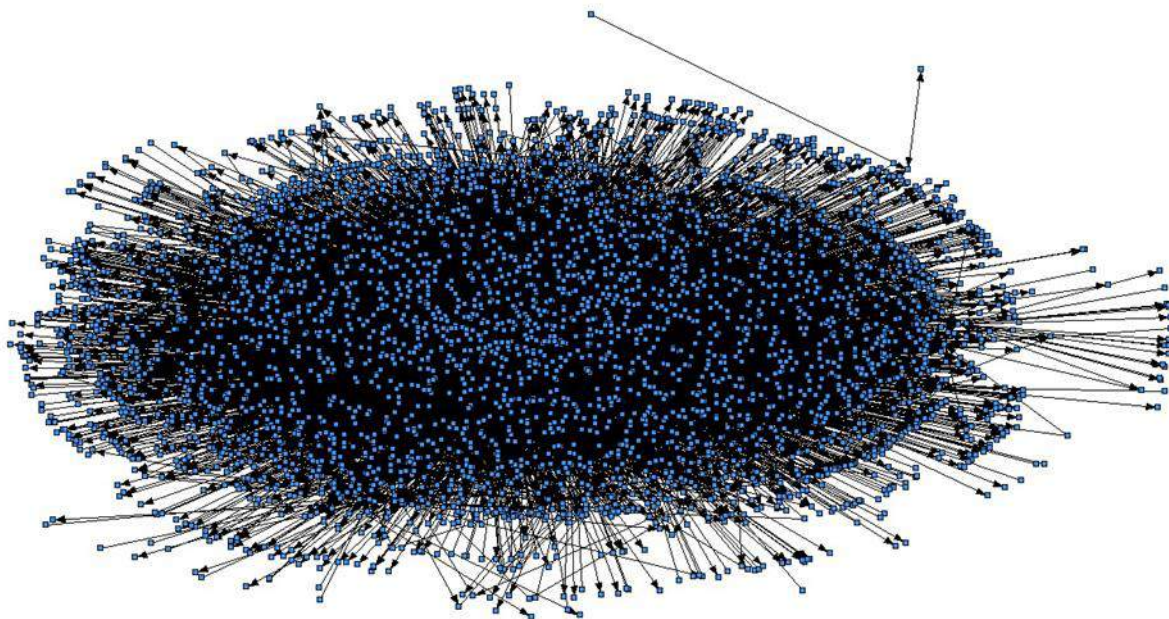


Figure 1: Network diagram for the electronics industry

An analysis of the electronics industry network data (cf. Figure 1) reveals that 20% of the companies are responsible for 77.85% of the connections which seems to follow a power-law distribution. Consequently, few companies in the supply chain have disproportionately high number of connections while most other companies have only few connections within the network which is consistent with a scale-free and centralization network structure mentioned by Kim et al. (2015). Those structures are supposed to imply the network to be highly resilient to supply chain disruptions with a low probability of overall network failures being caused by node/arc level disruptions (cf. Kim et al., 2015). The existence of such structures may be inherent to the industry requirements as the electronics industry is characterized by rapidly changing technology and customer preferences (Sodhi and Lee, 2007). Consequently, disruptions can be extremely costly compared to other industries with a lower rate of technological change and more stable customer preferences. However, to take account for the fact that network structures seem to be more adequate for predicting network resilience than network metrics, further analysis of the network structures in the electronics industry would be required. In addition, a firm-level analysis will enable the assessment supply chain risks for the considered company as well as an analysis of potential cascading effects of supply chain disruptions.

## CONCLUSION

Although supply chain disruptions and the management of supply chain risks have frequently been considered in the literature, data-driven approaches creating end-to-end supply chain visibility based on publicly available information and by thus allowing a more efficient management of supply chain risks are scarce. The main contribution of this research is as follows. To our best knowledge, there are no studies looked into data-driven approaches for supply chain risk management in a real network setting. Unlike to the

previous papers of similar nature where simulated networks were used, we use a real network data from Bloomberg SPLC to improve visibility and uncover resilience based on network measures. Future research in this area could study network structures in other industries or take into account the relationship value between a company and its supplier or customer. Finally, considering geographical information and classifying companies by different regions, may allow assessing the impact of disruption in a particular geographic area caused, for example, by natural disasters.

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# SUPPLY CHAIN PLANNING UNDER RISK CONSTRAINT

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**Keywords:** Supply chain, planning model, goal programming, supply chain risk

**Abstract:** Supply chain risks(SCR) problems are considered to be one of the most important issues for both academics and practitioners in this field of supply chain management. With the multi-layer levels and the dynamic relationships within supply chain, modelling risks is becoming more complex and more difficult. A large number of modelling methods (i.e., optimization models, mathematical programming, analytical and simulation tools, etc.) have been proposed to manage and mitigate the level and the impacts of risks within supply chain networks. As a result, in this article , we tried to incorporate the risk into the supply chain model. Using a risk scores, an analysis is conducted to enable the company to better understand the potential impacts of any potential disruption on the entire supply chain and also to prioritize the supply chain risk management options. The analysis will be done through a multi-criteria model for a global supply chain planning, solved using goal programming.

## 1 INTRODUCTION

Supply chain risk is becoming nowadays one of the main issue that managers need to deal with to avoid or to mitigate its negative impacts on business continuity and performance ([4]-[13]). Different approaches have been introduced, modified and developed to address this issue. From design decisions to managing business operations, risk is involving in every step or process within supply chain networks [37]. However managing it, requires a certain maturity or awareness level of the necessity of applying suitable strategies to handle it or to considered it when making any decision within supply chain. This could explain why certain organizations are protected from the severe impacts of risks and why others have failed to deal with it [21].

## 2 Existing Frameworks

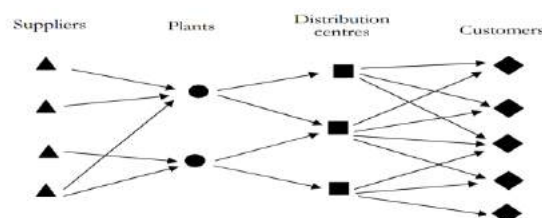
In this context, [1-5] argue that supply chain disruptions such as natural disasters, economic crises, terrorist attacks and disease such as SARS, have a negative impact on the performance of the supply chain. To justify their point of view, [1] present the example of two companies: Ericsson and Apple who have lost over then 400 million Euros due to: for Ericsson, a failure of the supplier which has created a production shutdown at Ericsson and then the loss of customers and damage brand image of the company. Regarding Apple, the company has lost customers because of earthquakes Tsunami in 1999 which led to a supply disruption in product components iPad 2 for more than two weeks and therefore the loss of customers and degradation of its reputation in the market. According to [2], 74% of managers stress the need to manage supply chain risks. According to the same report, organizations face today more than 24 sources of risks, with different levels of impacts and consequences. Findings reveal that the most common consequences of these risks are the loss of productivity (58%), customer



complaints (40%) and increased cost of working (39%), with annual cumulative losses of at least €1 million per year due to supply chain disruptions [2]. Thus protecting supply chains and making them less vulnerable to different types of disruptions have become one of the main priorities for both researchers [6-11] and practitioners (Resilience Report 2012, 2013 and 2015, Generix Group 2015, Accenture 2014, etc.), where there is a common consensus about the need to understand the causing factors of supply chain susceptibility to risks and the their occurrence impacts [2-5]. The attempts to give answers to these basic questions have been the topic of years of research and experiments, resulting in a plethora of tools, methods and practices that deal with different issues related to supply chain risks [4]. The need for an effective approach to manage supply chain risks seems apparent. [12-15] highlight that the search for a mitigation strategy or solution required first and foremost a clear understanding of what the supply chain risk concept means, which still missing in the literature review [4][15]. According to the authors, "the real challenge in the field of supply chain risk management is to be able to take advantage of risk through selecting and implementing the right mitigation options [28]. And to achieve this objective, risk need to be integrate in all related supply chain decisions. Thus most of published frameworks focus on either maintaining the coordination of supply chain through optimisation tools to guarantee the ideal conditions of supply chain functions, or developing recovery and mitigation models to minimize the impacts of risk after it occurrence. However, a scarcity of works have been developed to evaluate the cost between implanting mitigation tools or accepting the impacts of supply chain risks. To evaluate any of these options risk need to be considered as one of supply chain objectives. Interestingly, no study has been found which developed a quantitative recovery for managing sudden production disruption in a supply chain with multiple entities in each stage of the system. Aiming to address this issue, we developed in the paper a multi-objectives supply chain model that consider risk as an objective to optimized. Therefore, in this paper, we propose in the next section a multi-objectives model of supply chain solved using goal programming tool.

### 3 Proposed Model

To integrate risk in the supply chain model, we used a four multi-echelon supply chain (as described in the Figure below) used a simple model (Figure.1 ) composed by a set of suppliers, plant, distribution centres, customers.



**Figure 1: Supply chain**



## 2 Model formulation

The different index, variables and functions are represented in the Table.1. Risk is calculated as a function of a risk index multiplied by a quantity to determine its value. Risk index is computed in function of probability of occurrence, severity of risk and vulnerability dimensions.

**Table 1: Supply chain model notation**

Orientation	SC planning	
Notations	i	Finished Products: $i = 1, \dots, I$
	j	Raw Materials: $j = 1, \dots, J$
	k	Manufacturers Plants: $k = 1, \dots, K$
	s	Suppliers: $s = 1, \dots, S$
	m	Distribution centers: $d = 1, \dots, M$
	n	Customer zones: $n = 1, \dots, N$
	t	Time period: $t = 1, \dots, T$
	q	Mode of transportation $q=1$ (Air), $q=2$ (Road), $q=3$ (Rail), $q=4$ (Ocean)
Parameters	$d_{int}$	demand for customer 'n' during time period 't'
	$SP_i$	Price of one unit of finished product
	$h_k$	Capacity of production at manufacturer 'k'
	$CAP_k$	Inventory storage capacity at manufacturer k of finished products
	$DCAP_m$	Inventory storage capacity at Distribution center D of finished products
	$CAP_{js}$	Inventory storage capacity of raw material at supplier j
	Pr	Pourcentage of demand that company desire to satisfy
	$\gamma_i$	Capacity requirements for product
	$\delta_{ij}$	No. of units of raw material 'j' needed to produce one unit of finished product "i"
	$\omega_{js}$	Cost of procuring one unit of raw material 'n' from supplier 's'
	$\lambda_{ik}$	Cost of producing one unit of finished product 'i' at plant 'k'
	$r_{im}$	Handling cost at distribution center per unit
	$ct1_{jskq}$	Cost transportation mode 'q' of raw material 'j' between supplier 's' to manufacturer 'k'
	$ct2_{ikmq}$	Cost transportation mode 'q' of product 'i' from manufacturer 'k' to centre of distribution 'm'
	$ct3_{imnq}$	Cost transportation mode 'q' of product 'i' from centre of distribution 'm' to customer 'n'
	$pcc_{int}$	Cost of loss demand
	$LT_k$	Production lead time at manufacturer 'k'
	$RI_{st}$	Risk index of manufacturer 'k' during time period 't'
	$RI_{dt}$	Risk index of distributor 'd' during time period 't'
	$RI_{st}$	Risk index of supplier 's' during time period 't'
	$RI_{nt}$	Risk index of customer 'n' during time period 't'
	$RI_{qt}$	Risk index of transportation mode 'q' between node 1 - node 2
	$DCAP_d$	Capacity of finished product inventory at distributor 'm'
	$MII_{mi}$	Initial inventory of finished product at distributor 'm'
	$MEI_{mi}$	Inventory of finished product at distributor 'm' at the end of planning horizon
	$KII_{kj}$	Initial inventory of raw material at manufacturer 'k'
	$KEI_{kj}$	Inventory of raw material at manufacturer 'k' at the end of planning horizon
	$KIF_{mi}$	Initial inventory of finished products at manufacturer 'k'
	$KFF_{mi}$	Inventory of finished products at manufacturer 'k' at the end of period t
	$IC_{jkt}$	Inventory holding cost per raw material 'j' per period at manufacturer 'k'

	$IC_{im}$ Inventory holding cost per finished product 'i' per period at distributor 'm' $RTI_{skq}$ Risk index of transportation mode "q" between supplier "s" to manufacturer "k" during time "t" $RTI_{kmq}$ Risk index of transportation mode "q" between manufacturer "k" to distributor "m" during time "t" $RTI_{mnq}$ Risk index of transportation mode "q" between distributor "m" to customer "n" during time "t"
<b>Decision Variables</b>	$X_{imnqt}$ Quantity of finished product shipped from distributor 'm' to customer 'n' using mode 'q', in period 't' $Z_{ikt}$ Quantity of finished product produced at manufacturer "k" at time period 't' (This will be ready for shipping after production lead time of $LT_m$ ) $Y_{ikmqt}$ Quantity of finished product that a centre of distribution "m" receive from manufacturer 'k' using mode 'q' in period 't' $V_{jsktq}$ Quantity of materials that a manufacturer "k" receives from supplier 's' using mode 'q' in period 't' $PUD_{int}$ Proportion of unfulfilled demand $F_{jkt}$ Inventory of raw material 'j' at manufacturer 'k' at the end of period 't' $F_{imt}$ Inventory of finished product at distributor 'm' in period 't' $F_{ikt}$ Inventory of finished product at distribution centre 'm' in period 't'
<b>Objective Function</b>	<p><b><u>Maximize profit= revenue from sales-(raw materials or purchasing costs + production costs + inventory holding costs + transportation costs)</u></b></p> <p>Profit = <math>\Phi - (TC1 + TC2 + TC3 + TC4 + TC5)</math>  Revenue from sales (<math>\Phi</math>) = <math>\sum_{t=1}^T \sum_{m=1}^M \sum_{n=1}^N \sum_{i=1}^I SP_i \sum_q^4 X_{imnqt}</math>  Production costs (TC1) = <math>\sum_{t=1}^T \sum_{k=1}^K \sum_{i=1}^I \lambda_{ikt} Z_{ikt}</math>  Procurement or raw materials purchasing costs (TC2) = <math>\sum_s^S \sum_j^J \sum_t^T w_{jst} \sum_k^K \sum_q^4 V_{jsktq}</math>  Handling (distribution) costs (TC3) = <math>\sum_t^T \sum_i^I \sum_m^M r_{imt} \sum_k^K \sum_q^4 Y_{ikmqt}</math>  Inventory costs (TC4) = <math>\sum_t^T \sum_m^M IC_{mt} \sum_i^I F_{imt} + \sum_t^T \sum_k^K IC_{kt} (\sum_j^J F_{jkt} + \sum_i^I F_{ikt})</math>  Transportation costs (TC5) = <math>\sum_t^T \sum_q^4 \sum_j^J \sum_s^S \sum_k^K CT_{jqskt} * V_{tqjsk} + \sum_t^T \sum_q^4 \sum_i^I \sum_k^K \sum_m^M CT_{qikmt} * Y_{qikmt} + \sum_t^T \sum_q^4 \sum_j^J \sum_s^S \sum_k^K CT_{iqmnt} * X_{iqmnt}</math></p> <p><b><u>Minimize unfulfillment demand</u></b>  Obj2 = <math>\sum_n^N \sum_i^I \sum_t^T PUD_{int} * pcc_{int}</math></p> <p><b><u>Minimize total risks</u></b>  Obj3 = <math>\sum_{t=1}^T \left\{ \sum_{s=1}^S (RI_{st} * \sum_{q=1}^4 \sum_{k=1}^K \sum_{j=1}^J V_{jsktq}) + \sum_{k=1}^K (RI_{kt} * \sum_{q=1}^4 \sum_{m=1}^M Y_{ikmqt}) + \sum_{m=1}^M (RI_{mt} * \sum_{q=1}^4 \sum_{r=1}^R X_{mnqt}) + \sum_{q=1}^4 \sum_{s=1}^S \sum_{k=1}^K (RTI_{skqt} * \sum_{j=1}^J V_{jsktq}) + \sum_{q=1}^4 \sum_{k=1}^K \sum_{m=1}^M (RTI_{kmqt} * Y_{kmqt}) + \sum_{q=1}^4 \sum_{k=1}^K \sum_{r=1}^R (RTI_{mrqt} * X_{mrqt}) \right\}</math></p>

Constraints	<p><b><u>C1: Demand constraint:</u></b></p> <p>- The first constraint equation deals with customer demand: In order to increase the profit, customer demand should be fulfilled. However, this couldn't be satisfy:</p> $\sum_n^N \sum_t^I X_{imnqt} + \sum_n^N \sum_t^I PUD_{int} \leq \sum_n^N \sum_t^I d_{in}, \quad \forall i, n, t$ <p>- the balance between products sold and demand.</p> $\sum_{m=1}^M X_{imnq} \leq d_{in}, \quad \forall i, n, t$ $\sum_n^N \sum_i^I PUD_{int} \leq (1 - PR)d_{in}, \quad \forall i, n, t$ <p><b><u>C2: Capacity constraints</u></b></p> <p><b><u>2.1 Supplier capacity constraints</u></b></p> $ML_{jst} \leq \sum_q^4 \sum_k^K V_{jsktq} \leq CAP_{jst} \quad \forall j \in J \text{ and } \forall s \in S$ <p><b><u>2.2 Manufacturer capacity constraints</u></b></p> <p><b><u>2.2.1 Production capacity</u></b></p> $ML_{ikt} \leq Z_{ik} \leq h_{ik} \quad \forall i \in I \text{ and } \forall k \in K$ <p><b><u>2.2.2 Storage capacity</u></b></p> $\sum_j^J F_{jkt} + \sum_i^I F_{ikt} \leq CAP_{kt} \quad \forall k, t$ <p><b><u>2.3 Centre of Distribution capacity constraints</u></b></p> $\sum_q \sum_m Y_{imkq(t-LT_{qmk})} + \sum_i^I F_{im(t-1)} \leq DCAP_{dmt} \quad \forall m \in M$ <p><b><u>Transportation capacity constraints</u></b></p> $MT_{qskt} \leq \sum_j V_{jqskt} \leq CAP_{qsk} \quad \forall j \in J, s \in S \text{ and } k \in K$ $MT_{qkmt} \leq \sum_i Y_{iqkm} \leq CAP_{qkm} \quad \forall i \in I, k \in K \text{ and } m \in M$ $MT_{qskt} \leq \sum_i X_{iqmn} \leq CAP_{qmn} \quad \forall i \in I, m \in M \text{ and } n \in N$ <p><b><u>C3: Balance constraints</u></b></p> <p><b><u>Supplier - Manufacturer balance</u></b></p> $\sum_{i \in I} \delta_{ji} Z_{ikt} \leq \sum_{s \in S} \sum_{q \in Q} V_{jqsk(t-LT_{qsk})} + F_{jk(t-1)} \quad \forall j \in J \text{ and } \forall k \in K$ $\sum_{i \in I} \delta_{ji} \sum_{k \in K} Z_{ik} \leq \sum_{s \in S} \sum_{q \in Q} \sum_{k \in K} V_{jqsk} \quad \forall j \in J$ <p><b><u>Manufacturer - Inventory balance</u></b></p> $F_{jkt} = F_{jk(t-1)} + \sum_s^S \sum_j^J V_{jqsk(t-LT_{qsk})} - \sum_i^I \delta_{ij} Z_{ikt} \quad \forall j, k, t$ $F_{jkt} = KEI_{kj} \quad \forall j, k, t$ <p><b><u>Manufacturer - CD</u></b></p>
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	$Z_{ik} \geq \sum_{m \in M} \sum_{q \in Q} Y_{iqmk} \quad \forall j \in J \text{ and } \forall k \in K$ $F_{ikt} = F_{ik(t-1)} + Z_{ikt} - \sum_m \sum_q Y_{iqkmt} \quad \forall i, k, t$ $F_{ikt} = KFF_{ki} \quad \forall i, k, t$ <p><u>Distribution centre - Inventory balance</u></p> $F_{mit} = F_{mi(t-1)} + \sum_k \sum_q Y_{iqkm(t-LT_{qkm})} - \sum_n \sum_q X_{iqmnt} \quad \forall i, m, n, t - LT \geq 0$ $F_{imt} = MII_{mi} \quad \forall i, m, t = T$ <p><u>Distribution centre - Customer: Quantity transported to customer cannot exceed the quantity available with CD</u></p> $F_{im(t-1)} + \sum_q \sum_m Y_{iqkmt} \geq \sum_{n \in N} \sum_{q \in Q} X_{iqmn} \quad \forall i \in I \text{ and } \forall m \in M$ <p><b><u>C4: Binary non negative constraints</u></b></p> $V_{jskq} \geq 0$ $Y_{ikmq} \geq 0$ $X_{imnq} \geq 0$ $Z_{ik} \geq 0$
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$$\begin{aligned} \text{Subject to} \quad & \text{Min } Z_{GPV} = F_1 e_1^- + F_2 e_2^+ + F_3 e_3^+ \\ & Z_1 + e_1^+ + e_1^- = Val_1 \quad (\text{Profit}) \quad (\text{eq. G1}) \\ & Z_2 + e_2^+ + e_2^- = Val_2 \quad (\text{Responsiveness}) \quad (\text{eq. G2}) \\ & Z_3 + e_3^+ + e_3^- = Val_3 \quad (\text{Risk}) \quad (\text{eq. G3}) \\ & e_1^+, e_1^- \geq 0 \quad \forall i = 1; 2; 3 \quad (\text{eq. G4}) \end{aligned}$$

Where

1.  $F_i$  represents the preference of decision maker of the different three objectives.
2.  $di$  is the expected deviation from reaching value of each goal. The value is represented by " $Val_i$ "
3.  $Val_i$  is the ideal value of each objective obtained by solving each objective alone ignoring the other two objectives.

$$\begin{aligned} \underline{VAL}_1 = & \{ [(\sum_{t=1}^T \sum_{m=1}^M \sum_{n=1}^N \sum_{i=1}^I SP_i \sum_q^4 X_{imnqt}) - [(\sum_{t=1}^T \sum_{k=1}^K \sum_{l=1}^L \lambda_{ikt} Z_{ikt}) + (\sum_s^S \sum_j^J \sum_t^T w_{jst} \sum_k^K \sum_q^4 V_{jsktq}) + \\ & \sum_t^T \sum_i^I \sum_m^M r_{imt} \sum_k^K \sum_q^4 Y_{ikmtq}) + \sum_t^T \sum_m^M IC_{mt} \sum_i^I F_{imt} + \sum_t^T \sum_k^K IC_{kt} (\sum_j^J F_{jkt} + \sum_i^I F_{ikt}) + (\sum_t^T \sum_q^4 \sum_j^J \sum_s^S \sum_k^K CT_{jqskt} * V_{tqjksk} + \\ & \sum_t^T \sum_q^4 \sum_i^I \sum_k^K \sum_m^M CT_{qikmt} * Y_{qikmt} + \sum_t^T \sum_q^4 \sum_j^J \sum_s^S \sum_k^K CT_{iqmnt} * X_{iqmnt})] \} L - e_1^+ + e_1^- \\ \underline{VAL}_2 = & [\sum_n^N \sum_i^I \sum_t^T PUD_{int} * pcc_{int}] - e_2^+ + e_2^- \\ \underline{VAL}_3 = & [\sum_{t=1}^T \{ \sum_{s=1}^S (RI_{st} * \sum_{q=1}^4 \sum_{k=1}^K \sum_{j=1}^J V_{jsktq}) + \sum_{k=1}^K (RI_{kt} * \sum_{q=1}^4 \sum_{m=1}^M Y_{ikmq}) + \sum_{m=1}^M (RI_{mt} \\ & * \sum_{q=1}^4 \sum_{r=1}^R X_{mnqr}) \\ & + \sum_{q=1}^4 \sum_{s=1}^S \sum_{k=1}^K (RTI_{skqt} * \sum_{j=1}^J V_{jsktq}) \\ & + \sum_{q=1}^4 \sum_{k=1}^K \sum_{m=1}^M (RTI_{kmqt} * Y_{kmqt}) + \sum_{q=1}^4 \sum_{k=1}^K \sum_{r=1}^R (RTI_{mrqt} * X_{mrqt}) \} ] - e_3^+ + e_3^- \end{aligned}$$

## 4 Conclusions

In this article, an essay was made to model supply chain under risk dimension. In the literature review, risk is usually considered as a constraint. In our model, risk is considered as one objective of supply chain that a manager wants to reach or to achieve. Starting by basing planning model of supply chain in which we integrate supply chain risk. Thus, three objectives have been defined in this model which are maximising profit through minimising costs, increasing responsiveness through maximising demand fulfilment and finally minimising risks. And as these three objectives are opposite, we use goal programming variant to solve this model. This research is still in its infancy stage and a deeper analysis and interpretations are expected. The need to test and solve this model is missing in this article that will help determine the feasibility of the proposed model.

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# EFFECTIVE USAGE OF REDUNDANCY AND FLEXIBILITY IN RESILIENT SUPPLY CHAINS

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## **Abstract**

### **Purpose of this paper:**

Since 2001 the study of supply chain resilience has a growing attention of academics and practitioners. It addresses the recovery of systems after unexpected changes (Kamalahmadi and Parast, 2016; Linnenluecke, 2015).

Flexibility and redundancy are two prominent principles used in the literature on the resilience of a system (Rice & Caniato 2003; Linnenluecke 2015). Redundancy contributes to the system's resistance and response to disruptions (Chopra and Sodhi, 2004), and flexibility helps system to adapt to a new situation (Christopher & Peck 2004). As each of these have cost implications, a fundamental question in supply chain resilience still widely debated is related to their importance and the conditions for which each of them should be emphasised (Kamalahmadi & Parast 2016). For example, in certain cases flexibility can improve efficient use of redundant resources (Hopp, 2008), while in others flexibility can hedge risks without having redundant resources (Stecke & Kumar 2009).

In both cases, prompt information about disruptions enhances decision making related to appropriate response (Wieland & Wallenburg 2013). This means that information sharing and supply chain visibility might play a critical role in supply chain resilience (Blackhurst et al., 2011; Ponis and Koronis, 2012; Brandon-Jones, Squire and Van Rossenberg, 2014). In this study, we propose that effective usage of redundancy and flexibility depends on timely information about disruptions and their impact on the firm and its supply chain. Thus, we aim to explore in what way redundancy and flexibility affect a firm's resilience and what is the importance of supply chain visibility and information sharing in this context.

### **Design/methodology/approach:**

This study is based on a review of recent academic papers on supply chain and firm resilience published in supply chain management related journals, as well as key theories and approaches that can be used as an introspective framework for deeper insight into constitutive elements resilience: redundancy, flexibility and visibility.

### **Findings:**

Our major findings address a) there is a need for a better understanding which conditions are beneficial to combine or generate trade-offs between redundancy and flexibility, and when flexibility should be combined with visibility in the supply chains and b) the influence of visibility and information sharing on resilient supply chains and companies are under-represented in studies. Our findings suggest that redundancy, flexibility and information sharing/visibility are pillars of a firm's resilience.

### **Value:**

Our research addresses fundamental issues related to the supply chain resilience: what are the academic insights on how to effectively use redundancy and flexibility, and what role information sharing and visibility have in it. This paper intends to clarify where the future directions are and contribute to the development of a theoretical perspective on supply chain resilience.

## INTRODUCTION

In the last decade supply chains increasingly face a variety of risks and disruptions: from economic crisis, political risks and natural disasters, to port closures, accidents in production or storage facilities or industrial strikes (Liu et al. 2017). Thus, companies and their supply chains have to respond appropriately to these risks and disruptions while keeping their competitive position on the global market or trying to improve it.

This is reflected in increased number of academic publications that stem from research projects conducted in multiple countries and universities. Already six journal and conference papers reported a literature reviews on supply chains resilience since the beginning of 2016, which indicates growing body of the literature on this topic.

The purpose of this paper is not to add one more literature review to this literature, but to focus on dominant principles associated with the supply chain resilience (Hohenstein et al. 2015; Ali et al. 2017): redundancy, flexibility and visibility.

Redundancy, flexibility and visibility are considered as separate drivers of supply chain resilience in multiple studies. Generally, *redundancy* is considered in the context of 'passive' protection from disruptions, while *flexibility* is considered in terms of switching to back-up plans and adaptation to the new circumstances caused by a disruption. Theory highlights underlying costs of redundancy and flexibility and points out inefficiency of the systems when these two principles are not balanced (Rice Jr. & Caniato 2003). As Annarelli and Nonino (2016) state, it is not sufficient to focus on the trade-off between the redundancy and flexibility: resilience needs to be part of a decision-making process. Decision-making processes require reliable inputs, not only about achieved performances, but also alerts about potential risks and disruptions. Supply chain *visibility* is also an important element of effective and efficient use of resources (Brandon-Jones et al. 2014), which is of the utmost importance in periods of disruptions. However, influence of information sharing and visibility to supply chain resilience is investigated only in a few studies (Kamalahmadi & Parast 2016). Moreover, as redundancy contributes to the system's resistance and response to disruptions (Chopra and Sodhi, 2004), and flexibility helps the system to adapt to a new situation (Christopher & Peck 2004), there is a question how information sharing and visibility affect effective use of redundancy and flexibility. A review of extant supply chain management literature shows that only in recent studies these elements were connected (Kamalahmadi and Parast, 2016). However, to the best of our knowledge, the relationship between redundancy, flexibility, and visibility in the context of resilient supply chains has not been considered a central part in any of these studies.

The paper is structured as follows: first, we present a literature review design, and subsequently we elaborate on the key findings. The findings are discussed by taking into account two aspects – redundancy, flexibility and visibility seen as 1) key driving principles/strategies of supply chain resilience and 2) key capabilities relevant for the process of resilience. We conclude the paper with the future research directions and reflection on limitations of our study.

## LITERATURE REVIEW DESIGN

To define the literature research framework, we preliminary reviewed recent studies that examine theoretical concepts of resilience: (Kamalahmadi & Parast 2016; Tukamuhabwa et al. 2015; Hohenstein et al. 2015; Ali et al. 2017; Linnenluecke 2015). We reviewed frameworks used on these studies and gaps they identified. In all these studies, the identified common denominators that impact resilience are redundancy and flexibility, as well as visibility. Though these elements are identified as important for achieving supply chain resilience, they are mostly considered independently.

*The publication period:* In the literature research on supply chain resilience, Kamalahmadi and Parast (2016) did not find many studies before 2000. Based on the work of (Sheffi 2005), the 9/11 event in 2001 in the US and later catastrophic events (e.g. tsunami of 2004; hurricane Katrina in 2005) is the cornerstone for expansion of a research on the supply chain resilience (Linnenluecke 2015). Thus, we identify this as the cut-off date for our search in the following databases: Science Direct, Ebsco (Business source premier), Emerald, Wiley and Taylor and Francis.



**Keywords and search:** The search is conducted in two cycles: the first cycle was based on the papers that contain following keywords: “supply chain”, “flexibility”, “redundancy” and “resilience”. This search resulted in 577 results. After that, in a second cycle, we refined the search by using two additional keywords: “information sharing” and “visibility”. This narrowed down the search results to 105 studies. After refinement, by using the same PRISMA procedure as Ali et al., (2017), we obtained in the first cycle 242 results, and in the second cycle 72 results. The distribution of these results shows that 1) supply chain resilience is a popular topic in the supply chain management literature; 2) redundancy and flexibility are key concepts used the literature on supply chain resilience; 3) the consideration of information sharing and visibility in context of resilience starts erratically in the period from 2003 to 2007 and then grows steadily from 2009 (Figure 1b), when supply chain resilience started being seen as a process that requires not only response and recovery, but also preparation (Ponomarov & Holcomb 2009)

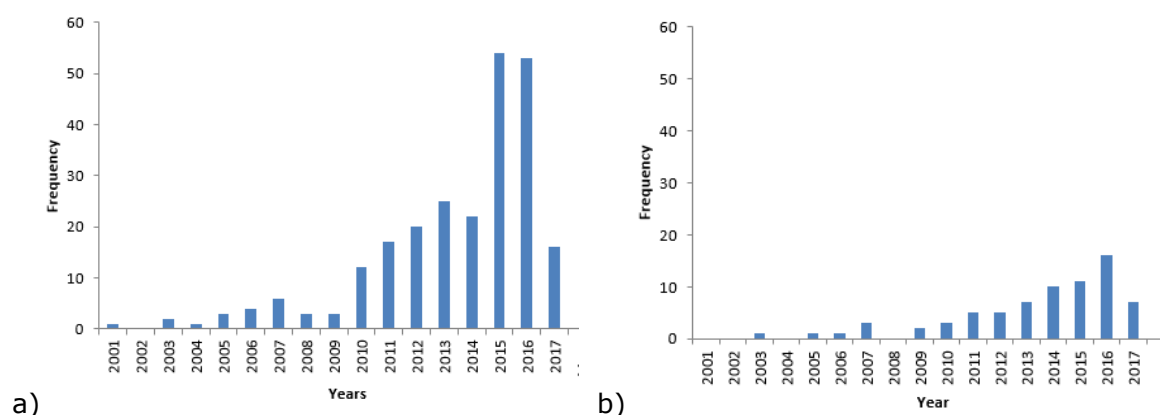


Figure 1. Distribution of publications in the period 2001-2017 (May) – a) keywords: “supply chain” resilience, flexibility, redundancy b) keywords: those used in a) and visibility and “information sharing”

**Content analysis:** For the purpose of this paper, we conducted content analysis on selected articles. In this analysis, we separated articles that are focused on redundancy, flexibility, visibility and information sharing as 1) key principles/strategies/drivers to achieve resilience, 2) capabilities of supply chains or companies to achieve resilience. In the group of articles focused on these key principles, we analysed the position of these elements in the used frameworks, e.g. are they primary elements that contribute to the resilience of a supply chain. In the group of articles focused on capabilities, we analysed these elements as part of proactive and reactive capabilities. Proactive capabilities mostly consider “planning for disruption” (Rice Jr. and Caniato, 2003), i.e., supply chain readiness and disruption detection, while reactive capabilities mostly consider response and recovery.

## FINDINGS AND DISCUSSION

In the supply chain management literature, resilience is considered from multiple angles – the overview of definitions of resilience can be found in following studies: (Ali et al. 2017; Tukamuhabwa et al. 2015; Hohenstein et al. 2015; Linnenluecke 2015; Kamalahmadi & Parast 2016).

Kamalahmadi and Parast, (2016) found that the majority of papers are related to investigation of resilience principles, were those principles are considered as resilience capabilities, antecedents or strategies. The focus of this study is on three key principles: redundancy, flexibility and visibility, and in further text we show preliminary findings on the depth of analysis of these principles in the context of supply chain resilience. Our analysis showed that these principles are rooted in work of researchers from MIT (Y. Sheffi, J. B. Rice, Jr) and Cranfield University (M. Cristopher and H. Peck).

Thus, we use early definitions of these elements as a starting point in our study. Redundancy entails maintaining capacity in the firm to respond to disruption, while

“flexibility entails creating capabilities in the firm’s organization to respond by using existing capacity that can be redirected or reallocated” (Rice Jr. & Caniato 2003, p.31). Supply chain visibility is the ability to see from one end of the chain to the other (Christopher & Peck 2004)

### Resilience principles: a hierarchical order

In line with Ali et al.( 2017), our review shows that flexibility and redundancy, and to the lesser extent visibility are key principles discussed and analysed in academic papers. In the papers focused on the literature reviews and surveys, these principles are often seen in hierarchical structure (Chowdhury & Quaddus 2017), that indicates which principles directly influence supply chain resilience (called first order elements), and which are part of related concepts (called higher order elements, e.g. second, third, etc.). These concepts indicate scope, i.e. what is the role of redundancy, flexibility and visibility in them, or they indicate depth, i.e., what are constitutive elements of redundancy, flexibility and visibility. Next to this hierarchical structure, there is a possible relationship between these elements in different hierarchical levels. An example of possible combinations is presented on the Figure 2.

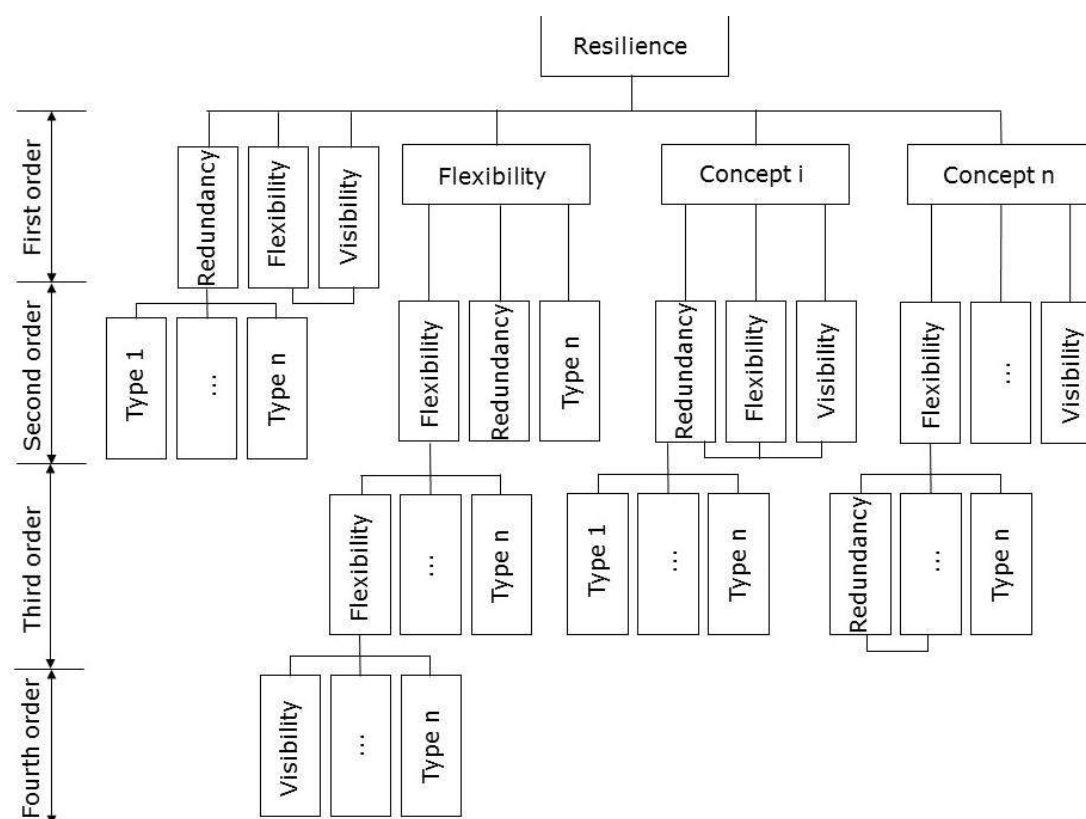


Figure 2. An example of a hierarchical position of elements considered in the analysis and possible relationships between them

Figure 2 suggest that despite of the consideration of redundancy, flexibility and visibility as key principles of supply chain resilience, there is no consensus in the literature about their relationship, as well as their placement in a hierarchical order. Ponomarov and Holcomb (2009) suggest that supply chain resilience should be seen in the context, in which case there is a need for recognition and classification of different contexts supply chain resilience appears in.

- *Redundancy, flexibility and visibility as the First Order elements:* Early studies on supply chain resilience consider redundancy and flexibility, as (one of) primary principles that directly influence supply chain resilience, while the importance of visibility is implied as a condition for rapid response to disruption (Sheffi, 2005) or

an element that can provide efficient use of flexibility (Rice and Caniato, 2003). Rice Jr. and Caniato (2003, p. 31) suggested that companies adopt a mixture of redundancy and flexibility, and that the perils of redundancy can be avoided by creating high visibility in the supply chain and increased efficiency. However, while there are studies that examine which principle provides higher resilience at lower costs (e.g. Carvalho et al., 2012), few of these studies consider the issue of visibility – in most studies it is assumed that there is an information and information sharing about the disruption which occurred somewhere in the chain.

- *Redundancy, flexibility and visibility as the Higher Order elements – in depth view:* There are studies which imply a direct connection between resilience and redundancy, flexibility or visibility, and then further develop in-depth analysis of these elements: for example, Ivanov et al. (2014) develops a model where supply chain resilience is directly related to system (structural and strategy part), process and product flexibility, and then redundancy is considered as part of structural flexibility, while visibility as recognized as important element, but not part of the model. There are also a few studies that examine connection between redundancy, flexibility and/or visibility: Brandon-Jones et al. (2014) develop a model considering that redundancy reduces the amount of information that needs to be processed, i.e. it influences supply chain visibility. Kamalahmadi and Parast (2016) suggest that information sharing and visibility represent possible first order elements, and that there is also an (obvious) connection between them which is not sufficiently studied in supply chain management literature. Similarly, Urciuoli et al. (2014) suggests that a connection between information sharing and flexibility needs more research.
  - *Redundancy, flexibility and visibility as the Higher Order elements – scope view:* Considered as higher order elements, flexibility, redundancy and visibility have various positions in our hierarchical model, as well as relationships between them. For example, in early work on supply chain resilience, Christopher and Peck (2004) considered redundancy and flexibility as part of the supply chain design, and supply chain design was part of the supply chain reengineering, the second order element. In later work, Kamalahmadi and Parast (2016) considered flexibility and redundancy as second order elements, as part of supply chain reengineering that directly affects supply chain resilience. Scholten et al. (2014), on the other hand, considered redundancy, efficiency and robustness as part of the first order element of supply chain reengineering, while flexibility is considered part of supply chain agility, another first order element.
- The most consistent view of visibility together with velocity/responsiveness is as a part of supply chain agility (Scholten et al., 2014; Tukamuhabwa et al., 2015; Kamalahmadi and Parast, 2016), though in some studies flexibility takes a place in the view of agility. Other concepts that consider redundancy, flexibility and/or visibility are for example: collaboration (Scholten et al. 2014), integration (Liu et al. 2017), or frequency of information sharing (Carvalho et al. 2011). These examples suggest lack of consensus what are key elements of key concepts related to supply chain resilience and opens a door for further research.

### **The resilience process and its phases: capability view**

In recent literature, a number of studies took resilience as dynamic capability of a supply chain (Pal et al. 2014; Chowdhury & Quaddus 2017; Brusset & Teller 2017). As the dynamic capabilities view is a branch of the Resource Based View (RBV), dynamic capabilities are considered in the context of creating a competitive advantage. As Teece, Pisano and Shuen (1997, p. 516) define, dynamic capabilities are “the firm’s ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments”, and that way achieve competitive advantage.

In multiple studies, flexibility, redundancy and visibility are seen as both, proactive and reactive capabilities (Chowdhury & Quaddus 2017) or as strategies (Ivanov et al. 2014). This view has roots in disaster studies, where pre- and post-disaster activities are considered separately (Rose 2004). Most of recent studies consider three distinctive phases of resilience: readiness, response and recovery (Chowdhury & Quaddus 2016), though

there are studies that consider these phases in more details (e.g. Sheffi and Rice Jr., 2005). Considering recent advances in information availability, as well as importance of disruption detection (Sheffi 2005), we distinguish it as a separate phase/capability of supply chain resilience (Figure 3).

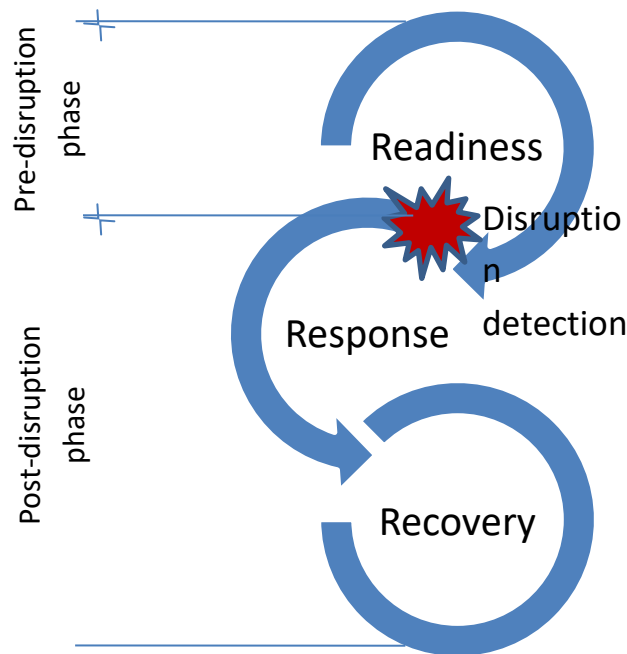


Figure 3. Phases of supply chain resilience

- In studies that consider a *proactive* view, supply chain readiness and disruption detection are important phases. Supply chain readiness is essential to overcome disruptive events and to develop resilient capability (Chowdhury and Quaddus, 2016). An emphasis is on planning and design of redundancy and flexibility into the supply chain, i.e., on preparation for a disruption (Pal et al., 2014) or disruption detection, i.e., visibility (Blackhurst et al. 2011; Brandon-Jones et al. 2014). Often the employed theory to analyse supply chain readiness is High Reliability Theory (HRT) (Weick 1987; Weick et al. 2008), which particularly focuses on high reliability organizations, avoidance of accidents and learning from them. Here, it would be interesting to explore role of redundancy, flexibility and visibility by using lens of HRT.

As Rice and Caniato (2003) state, both redundancy and flexibility come from investments in capital and capacity, and infrastructure and capabilities, respectively, prior to the point of need. Flexibility built in contingency plans and reasonable redundancy can increase level of readiness in the supply chain (Kleindorfer & Saad 2005; Chowdhury & Quaddus 2016). Visibility is a prerequisite for response to a disruption (Wieland & Wallenburg 2013), but there are scarce studies that consider visibility while evaluating redundancy and flexibility requirements. While information sharing is necessary to enable supply chain visibility and prepare for disruption by using early warning systems, practically it can be challenging as companies might want to hide their vulnerabilities from other supply chain members (Kleindorfer & Saad 2005).

- In studies that consider a *reactive* view, the emphasis is on operationalisation of capabilities (Rice Jr. & Caniato 2003) and evaluation, i.e., how redundancy, flexibility and visibility affect response and recovery. A supply chain's ability to "quickly respond to environmental forces, reconfigure resources and to recover quickly from vulnerabilities is an essential capability", and its recovery from disruption is a unique ability of supply chains (Chowdhury & Quaddus 2016).

Chowdhury and Quaddus (2016) also mention that recovery phase is often focused on cost and time of recovery, without in depth measurement of recovery efforts. Visibility, it is also important in the post-disruption phase, for quick coordination of recovery efforts (Brandon-Jones et al. 2014; Jüttner & Maklan 2011). Tracking and tracing (Brusset & Teller 2017), or supply chain event management (Ivanov et al. 2014) are part of early-warning systems that increase supply chain visibility. Information sharing is also one of enablers of visibility, though often overseen in connection to it. It has an important role in achieving efficient response, when connectedness between supply chain members, i.e., integration across logistics capabilities during the disruption enables supply chain resilience (Ponomarov & Holcomb 2009). Ponomarov and Holcomb (2009, p. 127) define connectedness as "systematic coordination of efforts to avoid duplication and wastefulness of services".

While redundancy and flexibility are core elements needed in each phase of supply chain resilience (Hohenstein et al. 2015), it is interesting that visibility and information sharing are under-researched; for example, disruption discovery is often taken as default, and not analysed as distinctive element, (e.g. Chowdhury and Quaddus, 2017; Hohenstein et al., 2015). Rather, this is part of studies focused on resilience analysis by using operations research methods.

## CONCLUSION

Based on the reviewed literature, we conclude the following key points:

- In line with Tukamuhabwa et al. (2015), who examined several principles/strategies that contribute to supply chain resilience, we found that there is a need for a better understanding which conditions are beneficial to combine or generate trade-offs between redundancy and flexibility, and when flexibility should be combined with visibility in the supply chains. Moreover, as resilience is contextual feature (Ponomarov & Holcomb 2009), there is a need to investigate whether the same recommendations would apply for SMEs and companies in the developing countries.
- Despite being recognized as important in many studies on supply chain resilience, the influence of visibility and information sharing on resilient supply chains and companies are under-represented in studies. Annarelli and Nonino (2016) suggest that research on the impact of information systems on organizational resilience is a fruitful research direction. We confirm that this branch of research has high potential, considering the growing use of the Internet in business communications, as well as the rise of internet based platforms for data storage and business applications. Moreover, there are vast opportunities for multidisciplinary teams that would cover operations research, information technology and organizational sciences/supply chain management aspects (Ivanov et al. 2014)
- A limitation of this study is in the literature review design: we considered only studies that connect flexibility, redundancy and visibility in the context of supply chain resilience. We acknowledge existence of vast amount of studies on redundancy and flexibility in more context of robustness or risks in supply chains, which could provide better information how actually redundancy and flexibility can be combined, and what is the role of visibility in it. For example, (Brandon-Jones et al. 2014) investigated redundancy and visibility as moderating variables to disruption absorption and management. Moreover, there is a need to get more insight on what kind of redundancy, flexibility or visibility modern supply chains need to increase resilience. For example, Christopher and Holweg (2011) suggests investing in structural flexibility during turbulent times, i.e. flexibility of the supply network.

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# **STUDY OF SAFETY ASPECTS IN HANDLING HAZARDOUS MATERIAL TRANSPORTATION IN THE MIDDLE EAST**

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## **Abstract**

### **Purpose of this paper**

The transportation of hazardous materials exposes to major risk aspects not only for the personnel involved in transportation but for the environment as well. In view of this, the research aimed to identify various categorical risks that are to be identified, analysed and mitigated accordingly. As for the safety of the material and the transport, such factors as the flow, structure and volume of the material need to be examined continuously (Verma, 2009). The evaluation of the risk factors is thus essential for the safety of hazardous materials and its transportations.

### **Design/methodology/approach**

The proposed methodology follows with a comprehensive literature review of identifying the various hazardous materials and their degree of hazard-ness and then analysing the safety measures through an industry focused case study approach.

### **Findings**

The research develops an initial framework as well as measures of safety aspects in handling hazardous material transportations. The research identified some gaps in following safety aspects while Transporting Hazardous Materials in developing countries mainly from the Gulf Cooperation Council (GCC) countries logistical operations.

### **Research limitations/implications (if applicable)**

The research is therefore limited to the GCC region. Further, an in-depth understanding of safety aspects in handling hazardous material would help the logistics industry, in providing better proactive safety mechanism among the Logistics Service Providers (LSPs).

### **Practical implications (if applicable):**

The transportation of hazardous materials has always been existing as a critical business because of the magnitude of any mismanagement and operations. This can be attributed to the fact that it not only affects the environment but also the driver's /employees life at risk. In view of this the research contributes to both the theory and practice of material handling, transportation and logistics.

### **Paper Type: Research paper**

**Keywords:** *Logistics Service Providers, Hazardous materials; Gulf Cooperation Council*



## 1. Introduction

The collection, transport and disposal of waste material and other dangerous goods have today become a complex and crucial issue that requires be controlling and monitoring by rules governing the same. The problem is very complex so much so that many industrialized nations have framed specific rules and regulations and medical institutions have complied, irrespective of the fact whether they are a part of the public or private sector (Diaz et al., 2005). Management of biomedical waste is a special situation wherein exposure to risks and hazards are not limited to just the waste generators and operators, but will also extend to the entire community (Sandhu & Singh, 2003). Therefore, the collection, segregation and disposal of waste in a manner that is scientific and proper is of vital importance as it has the potential to mitigate the risks posed to health in people both in a direct and indirect manner, thereby reducing damage to the environment, flora and fauna (Centers for Disease Control and Prevention, 2003). Workers in healthcare sector stand exposed to blood and other body fluids daily, due to the nature of their routine functions and responsibilities at such healthcare facilities. Due to this, workers in healthcare sector stand exposed to the risk of infection as a result of pathogens borne by blood or other liquid.

A program that is effective and efficient for the management of waste generated by healthcare is a crucial aspect of the infection control program of the facility and as a result, plays a vital role in the qualitative care and occupational health of all staff employed at the facility. Management of waste has now manifested into a crucial issue since it poses serious potential health risks and environmental damage, occupying a focal place in national health policy and a lot of significant international interest has been focused on it.

## 2. Literature Review

A comprehensive manual on environmental management and various procedures was conceived and compiled by SHELL egypt in (1992). All the aspects of management encompassing policy and objectives including audit were covered in the manual. A chapter in the context of this paper, titled "Operational Techniques" took into consideration various elements of management of waste (i.e. environmental management system, identification, characterization, inventorization, waste management hierarchy, treatment and disposal, handling and records, and plan integration). The chapter comprised a list which classified waste products according to their source of generation, apart from inclusion of brief descriptions of particular techniques of waste treatment.

The problem of medical waste is increasing and it is projected that in the near future it will become more and more complex. The enforcement of strict environmental regulations has led to a situation wherein the expenses towards disposal of medical waste will increase manifold, resulting in increased cost of providing healthcare. And in all probability, these costs will be borne by the patient. An appropriate management plan for disposal of medical waste should ideally follow a cradle-to-grave approach (Meany & Pual, 1989). This would include the adoption of a standard operating procedure to focus on issues like as waste generation, segregation of waste, handling, storage, transportation, treatment and finally disposal. All the factors need to be included under regulations so as to be assured that there is no impact on either the occupational or environmental health. Additionally, the framework for management of medical waste needs to incorporate components like extending training modules to individuals handling the waste in various stages from generation till final disposal. Table 1 classifies the various goods and their degrees of hazardous tendencies.

Table 1. Classification of Hazardous materials

UN Class	Dangerous Goods	Division(s)	Classification
1	Explosives	1.1 – 1.6	Explosive
2	Gases	2.1	Flammable gas
		2.2	Non-flammable, non-toxic gas
		2.3	Toxic gas
3	Flammable liquid		Flammable liquid
4	Flammable solids	4.1	Flammable solid
		4.2	Spontaneously combustible substance
		4.3	Substance which in contact with water emits flammable gas
5	Oxidising substances	5.1	Oxidising substance
		5.2	Organic peroxide
6	Toxic substances	6.1	Toxic substance
		6.2	Infectious substance
7	Radioactive material		Radioactive material
8	Corrosive substances		Corrosive substance
9	Miscellaneous dangerous goods		Miscellaneous dangerous goods

In early 2001, An assessment of management of medical waste in the UAE was evaluated through surveys and on-site visits to many major hospitals in the nation. The results of the survey went through a process of updation later so as to reflect the present situation. The primary purpose of the survey was to assess the procedures in practice for the management of waste, and to identify additional scope for improving methods and processes of waste collection, handling and its disposal. The study's findings revealed that the average rate of medical waste that was generated at hospitals in the UAE is 1.95 kg/bed/d, and that had high variations (i.e. 0.2 to 4.5 kg/bed/d) among the hospitals that were surveyed. It is pertinent to note that though the total quantity of medical waste that was generated at hospitals in the UAE was established, almost all the hospitals surveyed had no clue regarding the estimated quantity of different types of medical waste that were generated.

Moreover, procedures need to be followed for storage and segregation of dangerous goods. The separation between any two different categories of hazardous materials is identified with the point of intersection mentioned in the table below. Codes are provided for each category such as A, B and C. Code A states that the distance between materials should be at a minimum of 3 metres, Code B states that the distance between materials should be at least 5 metres and Code C states that the minimum distance between the materials should be at least 10 metres (Dubai Municipality, 1997).

All the hospitals that were surveyed put in practice procedures for segregation for pathological, infectious, and sharp waste, but the segregation of chemical, pharmaceutical and pressurized containers was not practiced by the hospitals. The colour coding that was followed was that hospitals located in the Emirate of Abu Dhabi utilised red bags for the disposal of medical waste, whereas hospitals in other emirates utilised yellow bags. But, all the hospitals did not practice marking of the bags and containers that were disposed. Most of the hospitals in the UAE had a separate storage room on-site for storing medical waste. Similarly, the on-site transportation of medical waste for the purpose of incineration was carried out through specialised vehicles or trolleys. Likewise, the off-site

transportation of waste for treatment or for disposal is carried out through specialised vehicles. However, all the hospitals do not employ a system of tracking the waste (Al-Dahiri et al., 2008).

### **2.1 Safety aspects in Transporting Hazardous Materials**

Welles *et al.* (2004) indicated in their paper that around 21% of accidents related to chemicals occur during transport while the other reasons for accidents are - 39% due to failure of equipment and 33% due to human error. Fabiano *et al.* (2005) pointed out the major areas where there is higher probability for accidents to occur during transportation by road. They are; tunnels bend radii, slope, height gradient, traffic frequency of tank truck, dangerous goods trucks and other critical areas. Duan *et al.* (2011) discussed in their presentation regarding the reasons and environmental issues of accidents related to various chemicals of hazardous nature in China between the year 2000 and 2006. A vast majority of the accidents during this period were related to petroleum and chemical explosives.

In light of higher probability of accidents that involve vehicles used for the transport of hazardous chemicals, there is room for improvements in vehicle quality, drivers, and infrastructure such as condition of roads, highways and the basic amenities available for members of the crew. Wei *et al.* (2004) has averred that a majority of the accidents occur as a result of human error and failure of equipment. The improper release of goods or material that are explosive, inflammable and toxic, tend to be hazardous in routine life. In the event of an accident, intimation requires to be sent immediately to the concerned authorities which includes, the environmental protection agencies, police, fire departments, poison control centres, hospitals, local media, and personnel who are earmarked for rescue operations. Yang *et al.* (2010) observed that travel at high speeds on roads and the presences of densely populated residential areas adjoining the roads are a form of dangerous environment that result in accidents during the transport of hazardous chemicals.

The provisions of Central Motor Vehicle (CMV) rule 131 of India, stipulates that, it is the responsibility of the consigner to obtain the appropriate permit for the transportation of hazardous materials and to ensure that the driver or owner or the transporter is provided with complete and sufficient information regarding the hazardous materials that are being transported. Additionally, as per the provisions of CMV rule 132 which states that it is the responsibility of the owner or transporter to ensure that, apart from a valid registration and permit; the vehicle that transports such hazardous materials is safe and furnished with the necessary safety equipments and devices. It is also his responsibility to ensure that the driver who is detailed for the particular duty is trained in the handling and transport of hazardous materials and that he has been provided with sufficient and accurate information, in order to enable him to be in compliance with the different safety rules and regulations that are prescribed (Palanisamy et al., 2015).

Transportation by road or rail of hazardous material has many varied issues associated with it. The obstacles that need to be sorted out are many. One of the main issues relates to the transportation of large quantities through major cities of hazardous chemicals that are classified as "toxic by inhalation". Even without dispensing the consideration of public policy of permitting the transfer of risk from citizens of one category to another, routing decisions involve a great degree of risk and safety issues. Increasing exposure will result in compromise of safety. For instance, choice of a different route for the transportation may result in additional distance to be travelled and that additional distance may have infrastructure that is inappropriate to handle transport of hazardous materials. The alternative routes that have been chosen may not have the necessary emergency response capability

and may lack sufficient expertise in the handling of commodities that are dangerous in nature. The transfer of such hazardous materials from road transport to rail transport places a requirement on the rail industry to be more technologically advanced and competitive with a willingness to honour their obligations as a carrier to handle hazmat movements which are distinct from routine material movements. The dearth of accurate data on hazmat movement by road is particularly challenging. Hazmat movements places mandatory requirements such as sharing of information to permit proper preplanning and prioritization. This will result in an improved economic impact analysis and justification of mode movement. Developments on this aspect can potentially increase productivity and better utilisation of prevailing rail capacity (Spraggins, 2010).

More recently, Chia-Hsun Chang et al. (2015) The paper has assessed the various risks of container shipping operation across the rage of products by using a case study methodology, thus classified a total of 35 risk factors according to their impact. The research warrants further research need that focus on exploring appropriate factors analysis to evaluating their relative performance in managing container shipping operations. This research aims to fill the research gap partly by identifying those factors and assessing their impact on driver's satisfaction.

### 3. Research Objectives

Since it is an ongoing research project, the current aim of this paper is to *"identify the factors which are associated with overall satisfaction in relation to safety when transporting hazardous materials in the GCC region"*.

### 4. Theoretical Framework

The research is therefore developing the conceptual framework as the initial model conceived by identifying the various independent variables (IVs) and dependent variable (DV) as depicted in Figure 1. Driving policy, In-vehicle monitoring system, driver's fitness and alertness, warning labels according to the product classification and site management for safe warehousing and disposal are the major identified factors or drivers (IVs) impacting to the overall satisfaction of the safe transportation (DV).

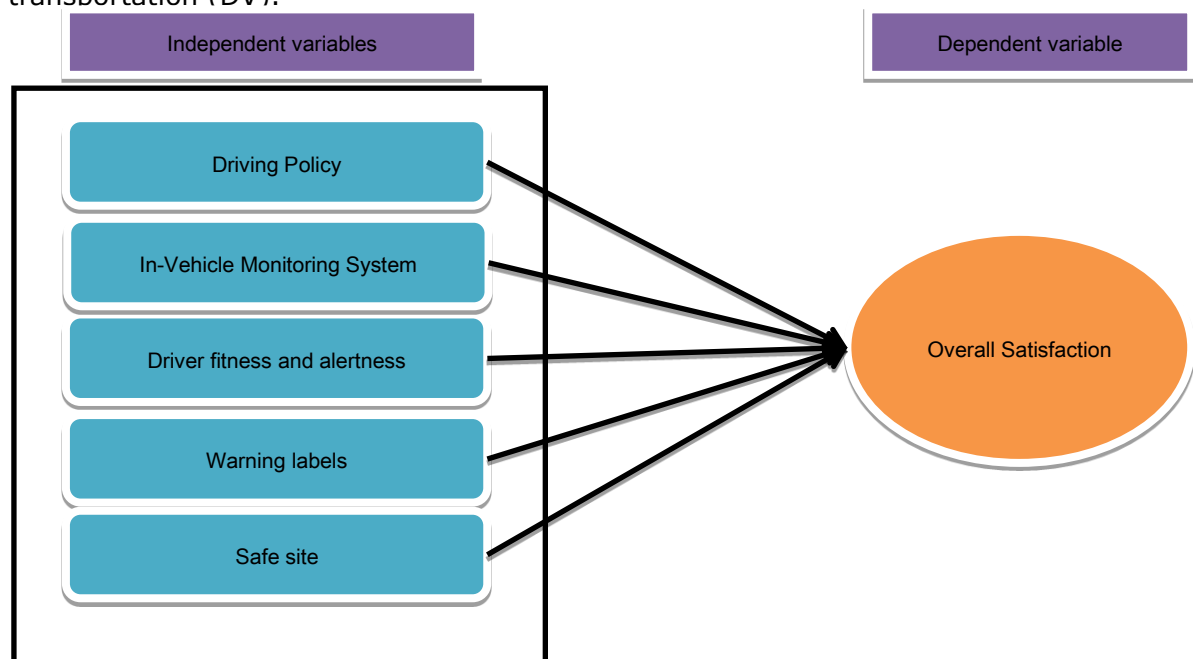


Figure 1. Conceptual research model with identified IV and DV

Therefore, the following hypotheses are developed according to the IV and DV relationship in order to identify root cause, and to have further analysis as a proactive approach and is suitable for anyone involved in accident / incident investigations.

*Hypothesis 1: Driving policy has a significant positive influence on the overall satisfaction when transporting hazardous materials*

*Hypothesis 2: Vehicle monitoring systems has a significant positive influence the overall satisfaction when transporting hazardous materials*

*Hypothesis 3: Driver fitness and alertness has a significant positive influence the overall satisfaction when transporting hazardous materials*

*Hypothesis 5: Warning labels has a significant positive influence the overall satisfaction when transporting hazardous materials*

*Hypothesis 6: Safe Site has a significant positive influence the overall satisfaction when transporting hazardous materials.*

## **5. Research Methodology**

Realistic deductive methods of research have been deployed in the present study. According to Bryman (2012) existing theories and frameworks are reassessed to arrive at relevant research questions and hypotheses. By such a reassessment a deductive research approach will be adopted. It is through this approach a theoretical framework will be created. It will be analysed to arrive at specific answers to the research questions as well. Since a deductive approach involves the analysis of the safety measures of transporting handling hazardous goods in UAE, it is the best suited approach for this study. The cause and effect of accidents happening in UAE can also be investigated through this approach.

The research methods, sampling strategies and techniques involved in data analysis are the major components in the study which will be determined by research strategy (Bailey, 1994). In this research a survey based questionnaire will be conducted in order to identify those factors and their interrelationships. In terms of measuring the types, frequencies, effect and cost incurred because of accidents survey will be the most appropriate method. It will also imply suggestions for improving the safety in such hazardous transportation (Elo et al., 2014)

## **6. Conclusion**

Transportation of hazardous materials is a dangerous activity wherein the need of observation is absolutely imperative. This can be attributed to the fact that it not only the environment that is affected but also the drivers/employees life at stake. In view of this, the present research develops a framework by secondary data and a focused case study. As for the types of materials that are being transported are identified that the company does not transport explosives, but transports gases, flammable liquids, flammable solids, oxidising substances, toxic substances, radioactive material, corrosive substances and other dangerous goods. The research is thus an ongoing research which is limited to the GCC region.

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## EMERGING RISKS DUE TO INEFFICIENT FLEXIBILITY

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### **Abstract**

#### **Purpose of this paper:**

Digitalism and increasing automation is nowadays recognized as the main field of actions concerning production systems, transforming them to smart factories. Increasing its flexibility, smart factories enable the system to capture resp. avoid occurring chances or risks. Thereby, flexibility will be considered as the potential of constant unaltered systems [Luft 2013 & Jacob 1989]. In this context flexibility is regarded as a dynamic target value which is linked to production system's performance. Once the system's flexibility is no longer sufficient, adaption processes are needed [Luft 2013]. Furthermore, oversized flexibility levels are considered as waste [Ren 2017], leading to adaption needs, either. Within measuring approaches for manufacturing flexibility, few authors address whether flexibility is subjected to waste or to inefficiencies. While wasted flexibility stands for mismatched flexibility level, inefficient flexibility means an idle potential remaining unused due to lacking awareness or incapacities. Thereon, this paper outlines the risk of disregarding idle (inefficient) flexibility in the context of production system adaptations.

#### **Design/methodology/approach:**

A literature review is used to show key input variables of existing measuring approaches and to analyze the consideration of idle flexibility within those methods. Based on this review, two theses are derived concerning the meaning of idle flexibility for the adaption of production systems. Those theses get supported by triangulation, applying three different flexibility assessment methods using an empirical data set.

#### **Findings:**

The literature review underlines the linkage between flexibility and the production system's performance, which bases on the multitude of performance related KPIs like cycle time, costs, capacities etc.

Following Ren, flexibility distinguishes in a necessary and an oversized (wasted) level [Ren 2017]. This paper reveals a further important segmentation, the inefficient level of flexibility (idle flexibility), which arises from non-optimal production processes and can be eliminated by optimization actions.

Hence, flexibility distinguishes in a real available but with inefficiencies afflicted part and a technical possible part. The gap between them stands for the inefficient (idle) flexibility.

#### **Value:**

The value of this paper is the mentioned distinction between real, idle and structural flexibility. Taking those flexibility segments into account, manager of production systems are able to precisely interpret flexibility measures and to derive nuanced decisions to alternate the system's flexibility and linked to that, the production system's performance.

#### **Research limitations/implications (if applicable):**

The paper is limited to lot sized production systems. Accordingly, transferability to supply chains and processual production systems has to be investigated.



## 1. INTRODUCTION

Digitalism and increasing automation are nowadays recognized as the main field of actions concerning production systems. The migration of assistance systems, artificial intelligence, social media etc. transform conventional production systems to smart factories, with the aim to cope with high dynamics and uncertainties. For example contemporaneously profound political events are a vital factor for the management of those systems. Previously stable global economic relations have to at least be scrutinized and analyzed concerning their effects on the economic production performance. Such circumstances increase the necessity of adaptability and manufacturing flexibility. The paper focuses on manufacturing flexibility, for which no measuring approach is generally accepted, helping the management evaluating the production systems flexibility and setting target values for system adaptations, although flexibility-based performance measurement appears as a fundamental requirement.

Thus, based on a specific definition of manufacturing flexibility, existing methods for assessing manufacturing flexibility will be analyzed regarding their functionality by a literature review within this paper. Furthermore, theses will be stated, which concern the existence of a new form of manufacturing flexibility, the idle flexibility. Empirical data will be used to proof its existence and to describe the risk, arising from the defiance of idle flexibility while using flexibility measures to evaluate systems performance or to adapt production systems.

## 2. LITERATURE REVIEW AND RESEARCH HYPOTHESES

At the beginning it was stated that production systems need flexibility and adaptability. While manufacturing flexibility enables production systems to capture resp. avoid occurring

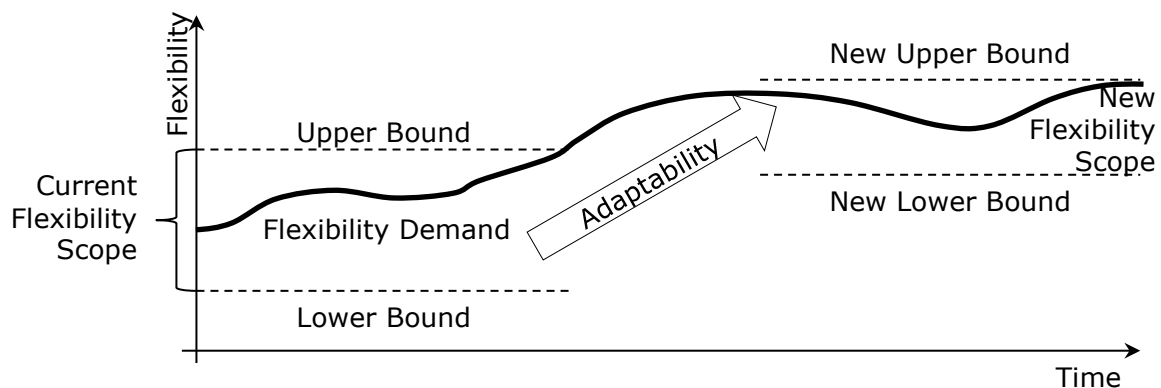


Figure 1: Coherence of flexibility and adaptability (Luft 2013)

sudden chances or risks, adaptability enables the alternation of the production system within a short period of time. Thereby, adaptability and manufacturing flexibility are often used synonymously. Publications of *Jacob* as well as *Luft* can be used to gain a precise distinction between manufacturing flexibility and adaptability.

*Jacob* draws a distinction between two types of flexibility, constituent and developing flexibility. Constituent flexibility includes the potential of an unaltered system including material flows, processes, resources etc. coping with changed circumstances. In case of developing flexibility the premise of an unaltered systems is rescinded. Thus, developing flexibility is regarded as the potential of changing the system with regard to composition and processes. (Jacob 1989) In a similar way *Luft* defines flexibility as a system immanent potential, which is available within upper and lower bounds and therefore acts as radius of operations, whereas he defines adaptability as the potential for active alterations. (Luft 2013) Despite of their different terms, *Jacob's* and *Luft's* definitions overlap concerning their meanings. Thus, manufacturing flexibility is a production system immanent potential, which is altered by developing flexibility resp. adaptability. *Luft* combines those two terms by determining a need of adaptability, if the boundaries of flexibility are reached and the current level of flexibility is no longer sufficient to cope with the relevant circumstances. (see Figure 1). In this case an adaption process is needed, which alters the boundaries of

manufacturing flexibility and determines the adaptability by time, costs and the effect of adaption. (Luft 2013) Furthermore an adaption process is needed, if an oversized flexibility scope is noted. In this case flexibility can be characterized as waste (Ren 2017).

In context of impending flexibility deficits or oversized flexibility ranges triggering adaption processes, it has to be investigated, whether existing manufacturing flexibility measuring approaches are sufficient to determine the necessary parameters of adaption processes. Such parameters include the adequate ascertainment of the need for adaptations, i.e. the investigation of the current range of flexibility including the comparison with the future need of flexibility. Furthermore, those measuring approaches have to be suitable to derive the right target figures and actions to be taken, which define the adaption process in respect of alignment and execution, i.e. the future level of flexibility and the therefor needed time and expenses. If those requirements are not fulfilled, the risk of misguided investments arises accompanied by according impacts on the production system's thrift.

Based on a literature review, 17 methods for measuring manufacturing flexibility have been identified and analyzed in respect of their functionality. Most of those methods focus on specific problem areas and system extracts. For instance, *Roscher's* approach is designed for the flexibility of vehicle assembly systems, which is measured based on the (estimated) operating costs (Roscher 2007). However, *Alexopoulos et al.* focus on the flexibility on punching departments (Alexopoulos et al. 2005) and *Wahab et al.* designed their approach in respect of the capability of machineries (Wahab et al. 2008). Even within the other methods such restrictions can be stated, with the result that any needs of adaption that may arise are limited to the related object of investigation. Furthermore it has to be considered that methods like those of *Alexopoulos et al.* (alexopoulos et al. 2005) or *Heger* (Heger 2007) are basically not designed to identify a need of adaptations, but to evaluate actions to be taken based on an existing need of adaption.

Beside the problematic nature of limited objects of investigation and the deviant intended use, the flexibility measures' quality is affected by subjective influences. These include weighing factors or estimations, which are included in the calculation process. Thereby, the impact of these factors is very divergent. While methods like those of *Bernard* (Bernard 2000) or *Vähning* (Vähning 1985) almost solely use subjective factors, they are used as supplements within other approaches. For instance, the flexibility measure is adjusted by using weighing factors expressing a process' importance, within the approach of *Wahab et al.* (Wahab et al. 2008). Hence, a lacking suitability of the existing methods for determining a need for an adaption of the whole production system due to subjective factors and specific intended uses can be stated. Even if such drawbacks will be removed, a proper suitability can still not be stated. It has to be investigated, if the methods computation logic and statements are nuanced enough, to provide reliable results.

Thus, relevant input variables of the existing methods are shown in Table 1. Beside the aforementioned weighing factor, data of time, costs, capacities, volumes and processes are often used. Process data in this case mean consideration of divergent and product variant depending process chains. Furthermore, several approaches use data of sales, quality, probability and binary factors. The latter are often used to express the assignment of different system elements, e.g. processes and resources.

<b>Input Variable</b>	<b>Author's indexes</b>	<b>List of all Authors with indexes</b>
Process	D; F; N; P; Q;	A: Alexopoulos et al. 2007 <b>B:</b> Alexopoulos et al. 2005 <b>C:</b> Bernard 2000 <b>D:</b> Bochmann et al. 2015 <b>E:</b> Chakravarty 1989 <b>F:</b> Chen & Chung 1996 <b>G:</b> Chou et al. 2008 <b>H:</b> Heger 2007 <b>I:</b> Krinsky et al. 1990 <b>J:</b> Meier-Barthold 1999 <b>K:</b> Rogalski 2011 <b>L:</b> Roscher 2007 <b>M:</b> Seebacher & Winkler 2013 <b>N:</b> Stockton & Bateman 1995 <b>O:</b> Vähning 1985 <b>P:</b> Wahab et al. 2008 <b>Q:</b> Zäh & Müller 2007
Cycle Time	A; D; E; K; L; M; P; Q;	
Production Costs	A; I; K; L; P; Q;	
Machine Capacity	B; E; I; K; L; M; Q;	
Turnover	B; K;	
Production Volume	B; I; (K); L; M; Q;	
Quality	I;	
Weighting factor	C; F; H; J; O; P;	
Probability	A; I; P;	
Number (binary)	D; F; G; J; N; P;	

Table 1: Summary of used main input variables in existing manufacturing flexibility measuring approaches

The emphasis of the used input variables lies upon dynamic performance metrics. Thus manufacturing flexibility as output of those measuring approaches underlies such dynamic conditions, why it alters in passage of time. A consideration of this time depending flexibility level is not to be recognized among the methods. Furthermore, it has to be stated, that human factors are mostly ignored, although they are essential for the production systems performance. Depending on his qualification and skills, occurring problems are identified and solved. Likewise this means that available alternative provisions will be ignored resp. not be recognized and used in some circumstances. Due to such a negligence of existing scopes, only a part of the existing flexibility will be used. Accordingly, the space between upper and lower bound of manufacturing flexibility shrinks. The occurring difference between the technical possible flexibility scope and the recognized and actually available flexibility scope can be considered as idle flexibility. Based on that, two theses can be derived, which will be analyzed in the subsequent chapters (see Table 2).

T1	The higher the degree of idle flexibility, the more the performance of the production system can be optimized.
T2	Due to idle flexibility, pseudo-scopes and pseudo-needs for adaption occur so adaption processes will be considered as needed. Thus, adaption processes may be launched to an inappropriate point of time and to an inappropriate target.

Table 2: Theses concerning idle flexibility

Thus the coherence between idle flexibility, production systems performance and risks for adaption processes will be investigated with the assistance of a case study.

### 3. RESEARCH METHODOLOGY

A use case based triangulation will be applied to examine the validity of the aforementioned theses, which means that they are investigated from three different perspectives using three different assessment approaches.

The use case bases on a data set given by a small medium enterprise. The production system of this enterprise is distinguished into three parts. Within part I and II half finished goods are produced and get stored in an intermediate store, from which they get called by part III. The task of part III is the assembling of the half finished goods to salable end products. Thus, make-to-stock principle is used within part I and II, make-to-order principle is used within part III. In total 47 resources are used in the production system. While those resources are mainly machines in the parts I and II, the resources of part III are mainly standardized stripping desks. The data set covers a period of time from October 2015 to October 2016 and includes work plans, parts lists, work rotas and schedules of activities for each resource, which enabled the calculation of order based lead times. Based on those data the measuring approaches of *Rogalski*, *Chen* and *Chung* resp. *Stockton* and

*Bateman* plus *Seebacher* and *Winkler* will be used to compute three different flexibility measures to meet the requirements of the triangulation method of three different perspectives.

In *Rogalski*'s work a break-even-point ( $x_{BE}$ ) is calculated for each working system based on generated added values and the related production costs. This specific point, expressed as utilization grade, has to be regarded as the minimum utilization and thus as lower bound of the flexibility scope. The upper bound is set by the capacity of the observed system ( $x_{max}$ ). The flexibility is finally computed by the gap between break-even-point and maximum capacity in relation to maximum capacity (see equation 1). The bigger the gap, the more flexible the system will be. (Rogalski 2011)

$$F_{Vol} = \frac{x_{max} - x_{BE}}{x_{max}} \quad (1) \text{ Volume flexibility}$$

Within the approach of *Stockton* and *Bateman* as well as *Chen* and *Chung* machine flexibility is calculated in respect of the resource's capability based on binary variables. The more processes ( $p_{cap}$ ) a resource is capable of in relation to the total number of processes ( $p_{total}$ ), the higher the flexibility. This can be expressed with equation 2. (Chen & Chung 1996, Stockton & Bateman 1995) Following this approach, for each resource the number of feasible processes will be divided by the total number of processes available. Therefore, this measure will not exceed the maximum of 100%.

$$F_{machine} = \frac{p_{cap}}{p_{total}} \quad (2) \text{ Machine flexibility}$$

*Seebacher* and *Winkler* propose a method for measuring capacity flexibility based on a monitoring chart (see Figure 2).

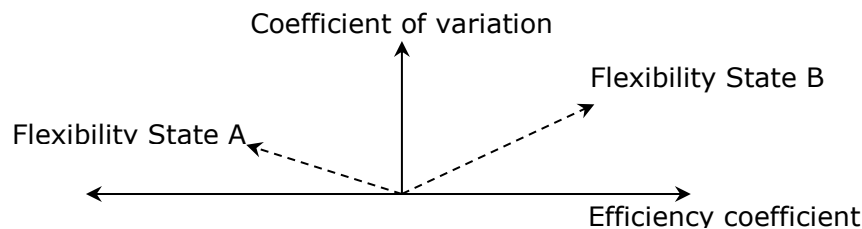


Figure 2: Flexibility efficiency monitoring chart (Seebacher & Winkler 2013)

The ordinate of this chart symbolizes the variation coefficient ( $v$ ), which provides information about variations in lead time. The abscissa is scaled with an efficiency coefficient ( $\varepsilon$ ), which provides information about the ratio between net productive time ( $C_{net}$ ) and available machine capacity ( $C_{max}$ ). The capacity flexibility finally results from the vector which consists of those two mentioned coordinates. Thereby it remains valid, that a system is more flexible, the shorter the vector is. (Seebacher & Winkler 2013) The computed flexibility measure is finally based on the following equation 3.

$$F_{capa} = \sqrt{\varepsilon^2 + v^2}, \quad \varepsilon = \frac{C_{net}}{C_{max}} \quad (3) \text{ Capacity flexibility}$$

Using two different data sets, scheduled and real data, two flexibility measures for each approach will be computed. The difference between those two measures will be defined as idle flexibility (see equation 4).

$$F_{Idle} = F_{sched} - F_{real} = F_I - F_{II} \quad (4) \text{ Idle flexibility}$$

#### 4. RESULTS AND FINDINGS

Within the following segments the results of the analysis will be introduced. The conclusive interpretation in respect of their impact on the flexibility measuring process as well as adaption processes will be made in the last chapter.

### Dynamic influences in volume flexibility

An overview over the volume flexibility of six selected resources, based on *Rogalski's* approach is given in Table 3.

Production Area	Cell	Break-Even-Point I	Volume Flexibility I	Break-Even-Point II	Volume Flexibility II	Idle Flexibility
I	A	9,25%	90,75%	15,02%	84,98%	5,77%
I	B	5,78%	94,22%	-78,96%	178,96%	-84,74%
II	A	28,84%	71,16%	47,83%	52,17%	18,99%
II	B	25,65%	74,35%	39,97%	60,03%	14,32%
III	A	0,44%	99,56%	1,05%	98,95%	0,61%
III	B	1,24%	98,76%	4,84%	95,16%	3,60%

Table 3: Range of volume flexibility based on *Rogalski's* approach

It can be stated, that resources in production area I and III need a low utilization, to operate cost-efficient. Their break-even-points (I) are below 10%. In contrast, resources of production area II need a higher utilization grade. Thus the scope of volume flexibility (I) of resources of Production area I and III are substantial bigger than those of production area II. This can be affiliated to higher process costs within production area II due to superior machines and higher added values per operation within production area I and III.

Regarding break-even-point II and scope of volume flexibility II, an analogical state can be identified. The difference between break-even-point I and II as well as between scope of flexibility I and II, is the used data set, for calculating these measures. While the measures with index I have been calculated based on scheduled lead times, real lead times have been used to calculate the measures with index II. Due to deviations of the planned lead times, which occur because of delayed material allocations, complex set up processes etc. the added value per operating minute shrinks. Thus the break-even-point defers to a higher utilization grade, wherefore the flexibility scope of volume flexibility shrinks. Simultaneously, the idle flexibility of each resource, except resource B of production area I, increases, the bigger the gap between both break-even-points at each resource will be. Furthermore, it has to be regarded, that the flexibility of resource B within production area I exceeds the 100% boundary. This means, that this specific resource is not operated cost-efficient. Those derivations within resource B or production area I are of such a grave kind, that this resource is not operated in a cost-efficient way.

### Dynamic influences in machine flexibility

The approach of *Stockton* and *Batemann* delivers machine flexibility I and II in Table 4. Thereby, machine flexibility II has been calculated by using the number of processes performed instead of the number of capable processes.

Production Area	Cell	Processes (total)	Processes (capable)	Machine Flexibility I	Processes (performed)	Machine Flexibility II	Idle Flexibility
I	A	18	1	5,56%	1	0,00%	5,56%
I	B	18	1	5,56%	1	0,00%	5,56%
II	A	269	7	2,60%	7	2,60%	0,00%
II	B	269	19	7,06%	15	5,58%	1,48%
III	A	1839	1700	92,44%	131	7,12%	85,32%
III	B	1839	1699	92,39%	94	5,11%	87,28%

Table 4: Range of machine flexibility based on *Stockton* and *Bateman*

While resources of production area I are not flexible and bound to one process type, resources of production area II are slightly flexible and resources within production area III are nearly utterly flexible concerning machine flexibility I. Compared with machine flexibility II, a nearly full usage of machine flexibility in production area II can be stated. Nearly every process the resources are capable of, has been operated. Considering production area III, nearly the opposite can be determined. Only few processes of the resources capability have been operated. Thus, machine flexibility II corresponds to only a fraction of machine flexibility I. Accordingly, the idle flexibility in production area III increases onto a high level, whereas it is nearly insignificant within production area II.

The main reason of the high idle flexibility within production area III is the fix allocation of processes to resources, which arises from static work plans which are recorded in the production systems ERP system. In addition, the employees of production planning department were not aware of the available alternative resources for each process. Thus they followed that very allocation given by the ERP system, increasing the idle flexibility. This means, that those specific resources obtain a low process mix and are used unilaterally concerning their process capability.

### Dynamic influences in capacity flexibility

Applying the method of *Seebacher* and *Winkler*, machine flexibility I and II have been calculated for several resources (see Table 5). Thereby, machine flexibility I is calculated based on the premise of an ideal and unimpeded production, where the net productive time corresponds the available capacity. Machine flexibility II disbands this premise, whereby lead time delays reduce the resources' efficiency.

Production Area	Cell	$v_{sched}$	$\varepsilon_{sched}$	Machine Flexibility I	$v_{real}$	$\varepsilon_{real}$	Machine Flexibility II	Idle Flexibility
I	A	0,0080	0	0,0080	0,0242	-1,0657	1,0660	1,0580
I	B	0,1050	0	0,1050	0,0181	-1,2364	0,7313	0,6263
II	A	0,0466	0	0,0466	0,0859	-0,3797	0,3893	0,3427
II	B	0,0348	0	0,0348	0,0605	-0,4929	0,4966	0,4618
III	A	0,0760	0	0,0760	0,1948	-0,1949	0,2755	0,1996
III	B	0,1685	0	0,1685	0,5123	-0,1748	0,8594	0,6909

Table 5: Range of machine flexibility based on *Seebacher* and *Winkler*

This method reveals, like the others, the existence of idle flexibility, as gap between machine flexibility I and II, which can be affiliated to delays in lead times, which were already identified as cause within the application of the *Rogalski* method. Due to this results, it has finally to be stated, that the resources stand in need of optimization of performance and flexibility usage.

## 5. DISCUSSION AND CONCLUSIONS

In accordance with the definition of manufacturing flexibility from the beginning of this paper and on the base of the presented results the proof of the existence of idle flexibility can be established (see Figure 3).

As gap between technically possible and realized flexibility, idle flexibility reflects the potential which remains unused by the system elements. As cause in the specific use case context, problems concerning production flow were mentioned, which can mostly but not exclusively be affiliated to human factors. In particular, existing alternative resources were not used because employees were not aware of those alternatives. Hence, an unilateral but recurring process mix deployed for each resource. Such a process mix becomes problematic in case of overallocated resources. Nescience of alternative resources implies the risk of an aggravating utilization situation, due to new orders which will not be redirected to other resources. Even in respect of lead times, idle flexibility has been detected, because of lacking provision of materials, problems during order processing und

delayed status information. Thus, the risk of missed delivery dates or of too long delivery times arises.

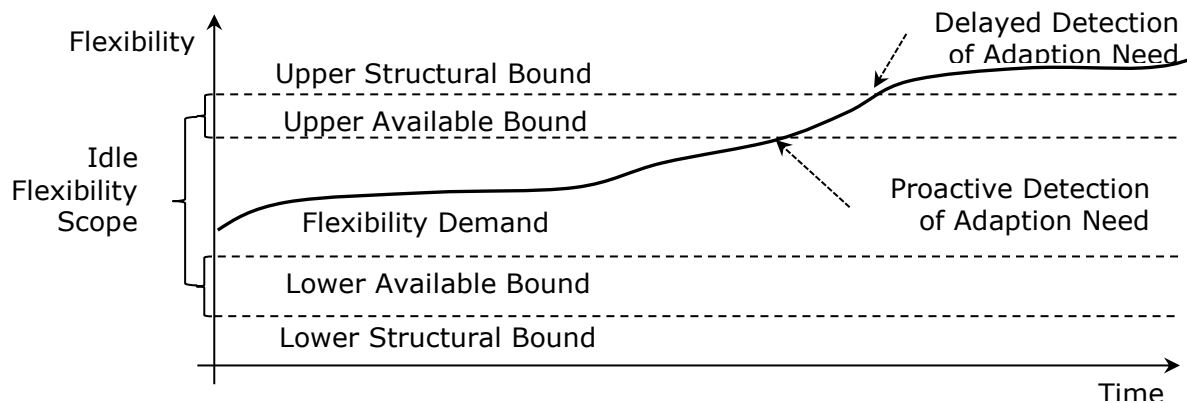


Figure 3: Coherence between idle flexibility and need for adaption

Furthermore, flexibility measurement methods which will be used to launch adaption processes using either scheduled or actual data are not sufficient enough to detect the need for adaption. Taking only one type of data into account, will deliver wrong adaption targets. Using scheduled data, while having a high idle flexibility, adaption needs will be detected to late, due to the fact that the real flexibility level already exceeded the boundaries of flexibility scopes. Delayed adaptations will be the result, including missed chances or risks coming true, which shall be used resp. avoided through adaptations. On the contrary, using actual data while having a high idle flexibility level adaption processes will be launched proactively, but under wrong conclusions, e.g. trying to solve lacking volume flexibilities by investing in new capacities, although process optimization, which decreases idle flexibility and increases the volume flexibility, would be a more suitable solution.

For achieving an adequate timely and problem-based derivation of the adaption need, it is inevitable to be aware of the structural (technical possible) and the real available flexibility level and further the gap between them (idle flexibility). Existing methods mostly neglect this gap, so they are subjected weak spots, concerning the applicability to measure flexibility in an appropriate way. Thus, both theses (T1 and T2) can be considered valid.

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## **Session 8: Transport and Distribution**

# SYSTEMIC COST OF RISK FOR HEAVY HAUL OPERATIONS IN SOUTH AFRICA

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## ABSTRACT

### Purpose

This paper compares the systemic cost of risk between the two heavy haul lines and general freight routes on the South African rail network to determine operational resilience of heavy haul rail systems in a growing export market. The Railway Safety Regulator in South Africa, requires permitted railway operators to report extrinsic incidents and intrinsic occurrences in a standardised manner, as well as direct costs aggregated for combined categories. Data recorded and categorized according to national standards recorded since 2009 provides insight into route-specific systemic cost of risk when related to the gross domestic product railed over time.

### Design

The 33,079 intrinsic occurrences and extrinsic incidents was geospatially superimposed to the nearest station on an existing audited rail freight flow model for South Africa. Reported railway occurrence cost was allocated on an average basis to the nearest station associated with an incident or occurrence. A leading business intelligence tool was used to query the combined database. Data was visualized using maps, animations and graphs.

### Findings

Results suggest that over time the heavy haul remote western iron ore export line exhibits superior route-specific systemic cost of risk when compared to the more populous coal export line over difficult terrain in the east, and the various general freight lines.

### Value

Evidence suggests that, in terms of systemic cost of risk, the heavy haul model is resilient in a growing market. The paper concludes that socio-economic factors, topography, and railway operational considerations contribute to systemic cost of risk.

## INTRODUCTION

The National Railway Safety Regulator Act No. 16 of 2002 of South Africa as amended (RSR Act) established the Railway Safety Regulator (RSR) as a juristic person comprising of a board, a chief executive and staff. The objects of the RSR are to: oversee safety (the lack of railway occurrences, fatalities, in-juries or damage within railway operations) of rail-way transport while operators remain responsible for such safety within their areas of responsibility; pro-mote improved safety performance in the railway transport industry in order to promote the use of rail as a mode of transportation; develop any regulations that

are required; monitor and ensure compliance; and give effect to the objects of the RSR Act. In terms of the RSR Act no railway operator (network, station or train operator) may undertake any railway operation or a component of a railway operation without being in possession of an applicable safety permit.

### **Cost of Risk**

Permitted railway operators must report to the RSR any railway occurrence, defined by the RSR Act as a railway accident or railway incident pre-scribed as such, which could include criminal activity, and the RSR must investigate them. The RSR must establish a national information and monitoring system regarding safe railway operations within the Republic that may include railway occurrences and security matters, and the Minister may make regulations prescribing the format. Railway occurrences can be conveniently separated into extrinsic incidents and intrinsic occurrences.

We define extrinsic incidents as security-related events reported by permitted railway operators or the general public to the South African Railway Police Service (SARPS) that fall outside of the normal activities associated with permitted railway operators. Extrinsic incidents are associated with intentional harm or damage to persons or property, and can include criminal activity. It is common cause in South Africa that cable theft and vandalism of metal structures severely impact the integrity of cabled field systems and dominates the extrinsic occurrence count.

We define intrinsic occurrences as safety-related operational events reported directly by permitted railway operators to the RSR experienced in the normal cause of business, excluding extrinsic incidents. Since 2006, permitted railway operators have declared railway occurrence event and cost data to the RSR for verification and inclusion in the RSR Database, using a prescribed data format (RSR 2009).

We define railway occurrence cost as the direct nominal cost reported to, and collated by, the RSR following any railway occurrence. As more data becomes available this definition may be revised to include consequential costs.

Railway occurrence cost is only meaningful when related to the associated corridor-specific economic activity. The associated economic activity for freight rail is the value of the commodities transported, effectively the transported gross domestic product. For a freight corridor we define cost of risk as the ratio of the railway occurrence cost to the nominal value of the commodity transported, both normalized for volume to Rand per metric tonne expressed as a percentage.

Since operating cost of a railway system is primarily characterised in terms of traffic density (Harris 1977. Graham 2003), we define systemic cost of risk as the cost of risk for a given level of traffic density.

### **Operational Resilience**

Operational resilience is defined as the emergent property of an organisation to continue carrying out its mission after disruption within its operational limit (Caralli 2010). Operational resilience of freight railways depends on many factors. Whereas the RSR measures extrinsic incidents and intrinsic occurrences as disruption, the traffic density and value addition can be viewed as proxies for the railway mission. Since these criteria are included in the definition of systemic cost of risk we propose that one way to determine operational resilience is simply to analyse the time variance of systemic cost of risk.

### **Specific rail corridors under consideration**

The analysis compares the 871 km western single-track export iron ore line (IO) and the 417 km east-ern double track export coal line (Coal) with the 966 km single track general freight rated manganese ex-port line operating a heavy haul tempo model (Mn), the 1589 km single-track Gauteng – Western Cape corridor (Capecor, also "Cape"), the 736 km

Gauteng – KwaZulu Natal corridor (Natcor) and selectively the 493 km Gauteng – Mpumalanga corridor (Maputo Corridor, also "Map").

The iron ore line from Sishen to Saldanha port is highly specialised and carry a small amount of domestic iron ore to a steel plant in the port of Saldanha as well as some manganese exports. Traffic along the coal line between Ermelo yard and port Richards Bay is split roughly 70/30 between export coal and other commodities classified as general freight. Manganese is exported between Postmasburg and Port Elizabeth, which traverses the Gauteng – Western Cape corridor for a fair portion of the route before joining the Gauteng – Port Elizabeth general freight line. The two dominant general freight corridors linking the Gauteng hinterland province to KwaZulu Natal (Natcor) and Western Cape (Capecor) respectively are included in the analysis to contrast the heavy haul operations. Table 1 shows the traffic volumes.

	General Freight	Heavy Haul	
		Export Coal (26 tonnes per axle)	Export Iron Ore (30 tonnes per axle)
2010/11	72.1	61.8	44.7
2011/12	73.7	62.2	46.2
2012/13	81.0	67.7	52.3
2013/14	82.6	69.2	55.9
2014/15	90.5	76.3	59.7
2015/16	84.0	72.1	58.1

Table 1: Rail traffic volumes in South Africa in million metric tonnes per annum (Transnet 2014 2016)

## RAILWAY OCCURRENCE DATABASE

Since 2010 the overall freight and passenger railway system remains stressed by unwanted extrinsic incidents emanating from the external environment and crossing the highly permeable system boundary into the railway system, which is further destabilized by intrinsic occurrences.

	Intrinsic Occurrences	Extrinsic Incidents
2010/11	4 181	6 379
2011/12	4 348	5 702
2012/13	4 262	4 124
2013/14	4 587	4 703
2014/15	4632	6 222
2015/16	4251	5 520

Table 2: Trends in national railway occurrences for all freight and passenger rail traffic. (RSR 2016)

Theft (65%) and vandalism (21%) dominated extrinsic incidents in 2015/16 (RSR 2016). Lopez (2001) determined that people will resort to crime if the probability of getting caught and the punishment for an offense is less than the expected payoff per offense, the cost incurred to commit the offense, and the expected payoff to perform alternative legitimate activities. Table 3 shows that extrinsic incident cost, including crime), is a relatively small component of railway occurrence cost. The compound effect of crime on cost of risk is not well understood.

	2013/14	2014/15	2015/16
Derailments (blue)	260.17	298.03	444.74
Collisions (green)	75.00	67.00	130.00
Train fires (yellow)	106.36	79.48	209.46
Level crossing accidents (orange)	47.16	73.32	13.48

Theft & vandalism (red)	53.00	74.00	92.00
Total	541.69	591.83	889.68

Table 3: Railway occurrence cost for freight and passenger in South Africa in Rand million. (RSR 2016)

### GEOGRAPHICAL INFORMATION SYSTEM AND DATA VISUALIZATION

The RSR database was uploaded using open source software distributions that are very well documented and regularly updated, and supported by rich online knowledge exchange forums and resources. From a technical perspective, the PostgreSQL system coupled with PostGIS are used as the spatial relational database management system (Spatial RDBMS) optimised for storing and querying spatial geometric data; and the QGIS geographic information system (GIS) software is used to visualise processed data stored in the Spatial RDBMS. The database of extrinsic incidents and intrinsic occurrences can be visualised in the time domain (Figure 1); in the frequency domain, which is the subject of ongoing research; or geospatially on maps (Figure 2).

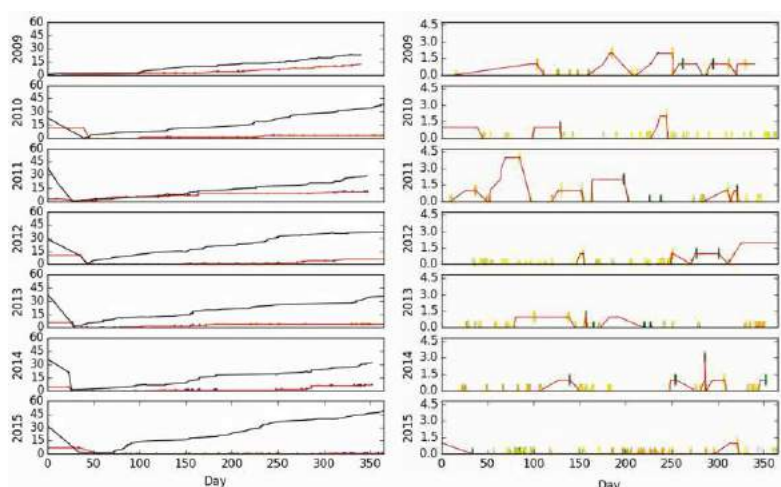


Figure 1: Cumulative build up and instantaneous time series of extrinsic incidents (red) and intrinsic occurrences (other colours) on the Iron Ore export line for calendar years 2009 - 2015.

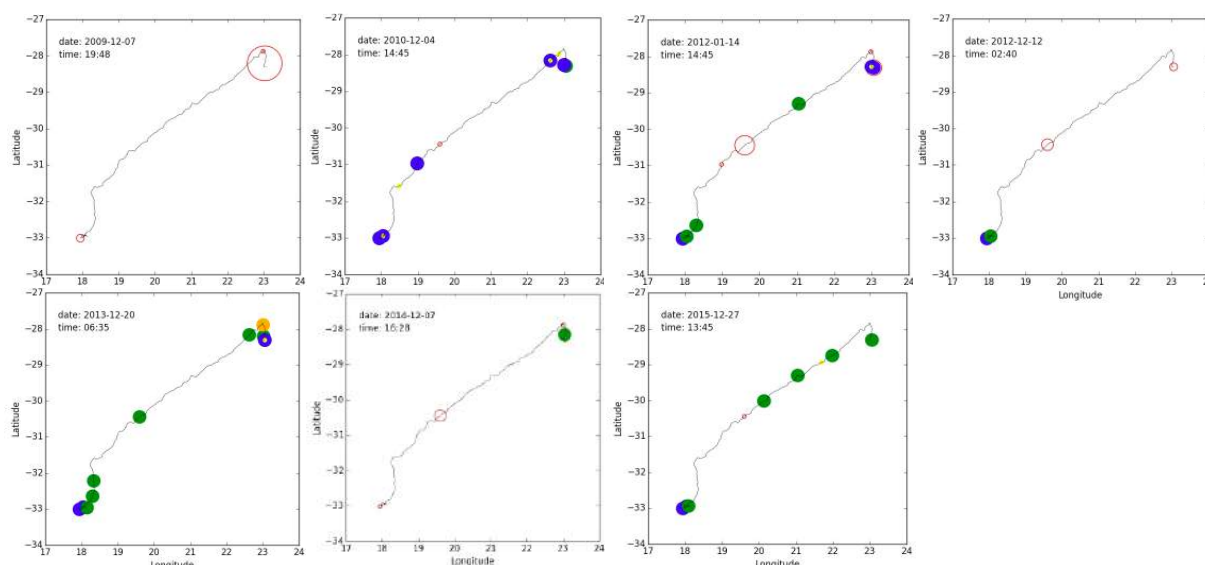


Figure 2: 2009 to 2015 annual build-up of railway occurrences relatively sized by count for the export Iron Ore line showing extrinsic incidents (hollow circles) and remnant intrinsic occurrences since the last extrinsic incident (coloured circles by type of cost).

## SYSTEMIC COST OF RISK

The annual counts of extrinsic incidents and intrinsic occurrences for the South African freight rail system over the observation period, listed in Table 4 and mapped to scale in Figure 3, suggest a persistent level of risk in operations.

	Extrinsic Incidents	Intrinsic Occurrences
2009/10	2 901	2 654
2010/11	2 680	2 450
2011/12	2 722	2 115
2012/13	1 985	2 004
2013/14	2 022	2 292
2014/15	2 199	2 200
2015/16	2 522	2 333
Total	17 031	16 048

Table 4: Extrinsic incidents and intrinsic occurrences reported to the Railway Safety Regulator (RSR 2016)

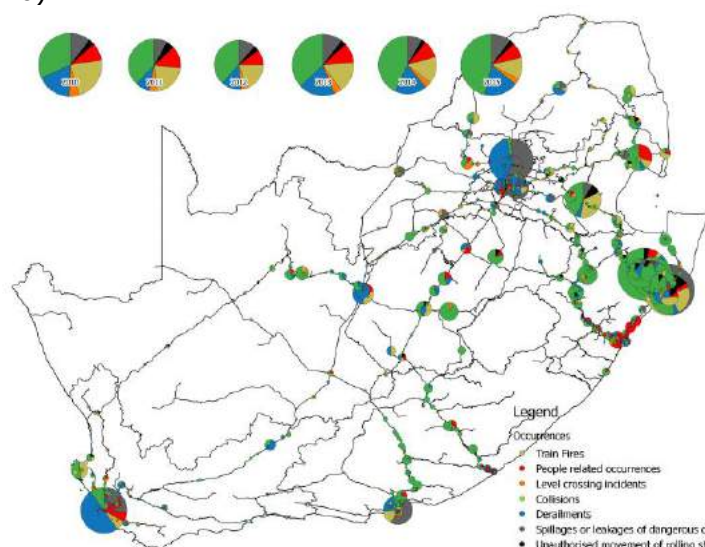


Figure 3: Total number of intrinsic occurrences and extrinsic incidents per railway occurrence cost category for freight only during 2015/16 also showing relative pie charts since 2010/11. (RSR 2016)

Although the percentage collisions are growing annually with high counts between Ermelo and Richards Bay, on the Natcor and on the manganese export line in 2015/16, this does not necessarily reflect the cost of risk on corridors.

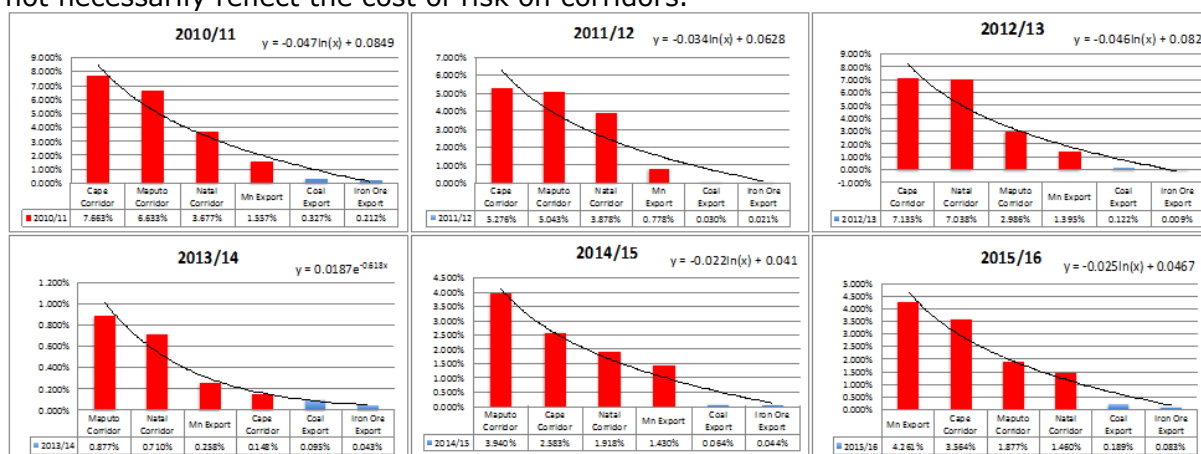


Figure 4: Systemic cost of risk for major corridors in South Africa in asymptotic sequence.

Figure 4 shows that the systemic cost of risk for the major corridors in South Africa exhibit asymptotic behaviour with freight density.

Figure 5 shows the normalized occurrence cost versus the economic utility for each major corridor during 2015/16, and Figure 6 shows how this relates to systemic cost of risk. Given the fixed cost nature of rail, we've assumed the long-term freight density for freight rail to be constant for the six-year observation period as shown in Table 5.

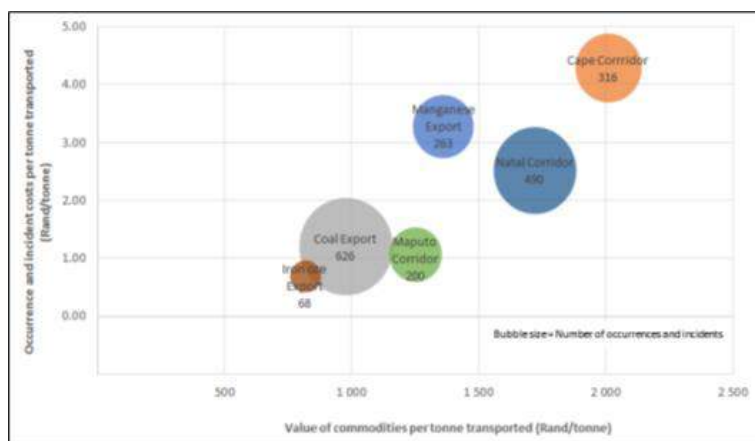


Figure 5: Railway occurrence counts and cost for the value of freight transported per major corridor 2015/16. (RSR, 2016)

Since 2010/11 the systemic cost of risk remained discernibly higher for red-indicated general freight corridor activity compared to blue-indicated heavy haul corridors.

It is quite possible that systemic cost of risk contains an element of systematic cost of risk, i.e. an artificial risk threshold programmed into the railway over many years using quasi-static conventions and imperfect policies procedures standards (PPSGs) and guidelines. If so, systemic cost of risk can be reduced through technical audits that review conventions, update PPSGs, identifies value-engineering opportunities prior to recapitalisation and restructuring interventions.

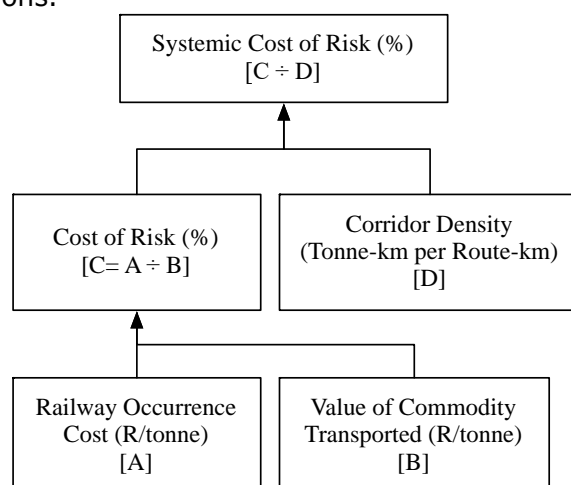


Figure 6: Systemic cost of risk

We note asymptotic behaviour of systemic cost of risk with freight density every year when we order the systemic cost of risk per corridor in descending order. Although the corridor order of red-marked general freight corridors vary from year to year, the heavy haul lines consistently occupy the lowest and second lowest systemic cost of risk. Furthermore the coal export corridor remains in second best position and the iron ore export corridor remains the systemic cost of risk leader.

## OPERATIONAL RESILIENCE

Operational resilience is defined as the emergent property of an organisation to continue carrying out its mission after disruption within its operational limit (Caralli, 2010). Operational resilience of freight railways depends on many factors.

	Export Coal line		Export Iron Ore line	
	Freight Volume (million tonnes)	Systemic cost of risk (%)	Freight Volume (million tonnes)	Systemic cost of risk (%)
2010/11	61.8	0.327	44.7	0.212
2011/12	62.2	0.030	46.2	0.021
2012/13	67.7	0.122	52.3	0.009
2013/14	69.2	0.124	55.9	0.043
2014/15	76.3	0.064	59.7	0.044
2015/16	72.1	0.189	58.1	0.083

Table 5: Systemic Cost of Risk and rail freight traffic volume for coal and iron ore exports from South Africa for 2010/16.

Railway operations on both the CapeCor and the Manganese export corridor carry interleaving traffic, which increases operational complexity. Challenging topography on the eastern escarpment tends to concentrate intrinsic occurrences and creates. Corridors originating and terminating in highly populated urban areas experience high numbers of localised extrinsic incidents that could increase systemic cost of risk. It is common cause in South Africa that cable theft and vandalism of metal structures severely impact the integrity of cabled field systems. These and many other factors drive systemic cost of risk. These merits of these assertions are part of on-going re-search.

Whereas the RSR measures extrinsic incidents and intrinsic occurrences as disruption of the safety envelope associated with a permitted operator, the traffic density and value addition can be viewed as proxies for the railway mission. Since these criteria are included in the definition of systemic cost of risk, we propose that one way to determine operational resilience is simply to analyse the time variance of systemic cost of risk. Table 5 and Figure 7 shows traffic volumes and systemic cost of risk for the two heavy haul lines in South Africa.

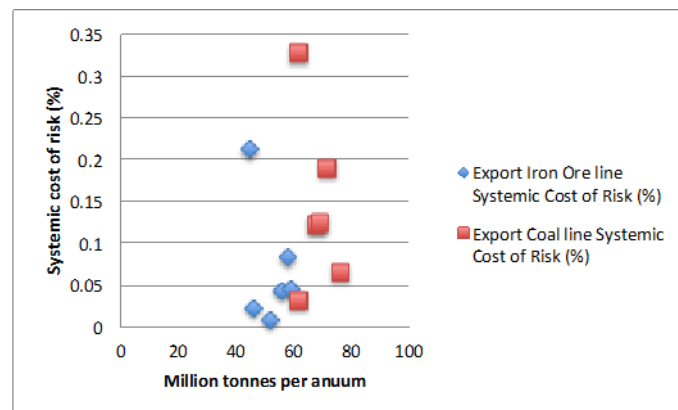


Figure 7: Systemic cost of risk for the heavy haul lines as traffic volume varied between 2010 and 2015.

## CONCLUSIONS

We can draw the following conclusions from rigorous analysis of the RSR data between calendar years 2009 and 2015. Firstly, geospatial visualization of the RSR database presents mental models to facilitate joint critical analysis of extrinsic incidents and intrinsic occurrences and testing of hypotheses. Secondly, railway occurrences remain manifold and evenly split between extrinsic incidents and intrinsic occurrences. Thirdly, the high-value/low-volume general freight corridors incur significantly more railway occurrences per



unit of density than the low-value/high-volume heavy haul corridors. Fourthly, the systemic cost of risk for heavy haul lines in South Africa is substantially lower than for general freight lines. Fifthly, the systemic cost of risk is asymptotic with traffic density and can be used as a convenient indicator of operational resilience for freight railways in South Africa.

## **RECOMMENDATIONS**

Further research towards improving operational resilience is required to develop a model for the relationship between extrinsic incidents and socio-economic factors; and between extrinsic incidents and intrinsic occurrences. It could also be beneficial to expand the analysis of cost of risk to include indirect costs such as opportunity costs, costs due to delays and environmental rehabilitation costs. In the interim a technical audit in concert with business interventions such as process reengineering, change management and supply chain reconfiguration could improve on the systemic cost of risk. The impact of extrinsic incidents on operational resilience could be mitigated through a revised social contract with wayside communities and focused corporate social investment.

## **ACKNOWLEDGEMENTS**

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# AN INVESTIGATION INTO PORT CONGESTION: THE LIBYAN CRISIS

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## **Abstract**

In the years following the Libyan revolution, Libyan ports experienced severe congestion from 2012 until 2014, arising from insufficient port capacity, incomplete management and poor operational practices. This led to delays in the supply chain due to ships waiting at anchor and queueing for berthing spaces across most Libyan ports. These logistic and operational challenges relating to port congestion are the focus of this paper. At the present time political and economic unrest in Libya is discouraging foreign direct investment, and negatively impacting on energy seaborne trade. However, as the political situation settles down in Libya, it is likely that the economy will recover and, as a consequence, port congestion will increase due to post-war economic development. In order to alleviate port congestion in the future it will be necessary for the Libyan Port Authority to understand what the existing situation is, and what the causes and drivers of the existing problems are. The research project on which this paper is based aims to investigate these logistic challenges in order to enhance the turnaround time of vessels, improve operational performance and manage costs more effectively. Data for daily operations and vessels movements (ship arrivals, waiting times, berthing times, departure times and berth throughputs) were collected for the Port of Misurata for the years from 2009 up to 2016. Using queuing theory to analyse the queueing behaviour of vessels in Libyan ports, we study whether berth utilization, shortages, and failures in port administration and policies are the main causes of Libyan Port congestion.

**Keywords:** Port Congestion, Queuing Theory, Ship Waiting Times and Misurata Port.

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## **Introduction**

In world trade and international transport, ports now more than ever before, have become widely recognized as crucial nodes in logistic chains. On the one hand, ports are the interface between the sea-side and land-side with the core activities of the loading and unloading of cargo. On the other hand, their activity became more integrated into supply chains represented by a larger share of chain total cost. For these reasons, the demand for port services continues to increase. However, port capacity does not always match demand. When demand exceeds capacity, due to a shortage of the latter, the main outcome is port congestion, thus, port congestion is a situation where capacity cannot cope with the growth in demand (Dragovic and et al., 2006). Congestion imposes high costs and results in time loss for both the port and ship owners, as well as being problematic for the other port actors, whereby delays can have an impact on supply chain networks and other ports of call. In most cases, especially in developing countries, when the economy of a country is improving, the traffic via its ports is increasing along with positive economic development (Oyatoye and et al., 2011). As a result, a queue of arriving vessels can form, and vessels may have to wait for longer periods to be serviced.

The increase in traffic normally coincides with a lack of adequate port infrastructure to handle excess cargoes causing delays in the final delivery of goods and generating higher transport costs. Congestion, in general, can appear in various forms in the port, it can be more or less hidden, presenting congestion surcharges or it can be visible presenting queues which continuously build up. Congestion is a global problem present in big ports as well as small ones. Congestion was prevalent in the past, and there is no reason to believe it will not exist in the future. Libyan ports have exacerbated congestion since the discovery of oil in 1959, the main driver of the Libyan economic growth. Over the years the traffic through Libyan ports has increased at a rapid rate alongside the economic development of the country, whereas, the existing port's facilities have not been able to match the increasing GDP and the associated increase in the country's international trade. Moreover, some policies issued by the Libyan government in 1977 turned out to be obstacles to any future developments of the Libyan ports. The worst periods of congestion Libyan ports have experienced was during 2012, 2013, and 2014 after the overthrown of the Qaddafi regime in response to the country's economic activity picking up due to an increase in exports and imports of goods and construction materials. This led to long waiting times for ships calling at Libyan ports. Libya now is politically unstable with three governments claiming legitimacy and armed clashes in some cities causing security risks, as a result of this crisis, oil exporting has been cut since early 2014 substantially hindering economic growth. The obvious impact on ports is significant reductions in traffic. However, as soon as the political situation settles down in Libya and oil exports resume, it is likely the

economy will start to grow again, and thus more port congestion should be expected. The main purposes of this research is to investigate the main drivers of congestion in Libyan ports and attempt to suggest changes to policies and management to improve efficiency. In this study we focus on port of Misurata as a case study, and apply queuing theory to ship waiting time patterns in order to investigate and capture congestion times, model the causes and suggest solutions. Thus, this study aims to investigate the main causes of congestion in Libyan ports (in particularly Misurata port) and find solutions to enhance quicker turnaround times of ships. The research questions are:

Research question 1: What are the main factors (drivers) causing congestion in Libyan ports?

Research question 2: What are the possible management solutions to solve congestion in Libyan ports?

This paper is organized as follows. The literature review section considers the types of congestion prevalent in seaports, the use of queuing theory to measure port congestion and congestion in Libyan ports. The data section describes the database used in the analysis. The subsequent section provides an analysis and the final section concludes the paper.

### **Libyan Ports**

Libya has 18 ports located along around 2000 Km of North African coast. Nine of these ports are general cargo ports, while the others are specialist industrial ports (oil ports, steel complex port and chemical ports). In addition to this classification, the National Planning Council (NPC, 2005) has classified the nine general cargo ports as either Major ports or Secondary ports. The major ports are Tripoli, Misurata, Elkhoms and Benghazi and these ports act as the main ports for handling the country's international trade. The secondary ports as classified by the NPC are Tubrok, Darnah, Alburagah, Ras Lanuf and Zowara and their role function is to support the major ports and serve only their surrounding area. According to UNCTAD's (1992) ports classification, Libyan general cargo and container ports are classified as small or medium ports and in term of their developmental stage, are somewhere between the first and second generation (Ghashat and Cullinane, 2013).

All of the Libyan ports are state-owned ports, and they fall under the public service port model, where the public port authority provides the complete range of services required for the functioning of the seaport system. All Libyan general cargo ports except Misurata are operated by a public company named the Libyan ports company (LPC), under the

authority of the Libyan Maritime Administration (LMA), and both of these public entities report to the same ministry (The Ministry of Transportation). The LPC was established in 1985 under the name of the Socialist Ports Company (SPCO) with the role of managing and operating all Libyan general cargo ports. However, in 2013 the company was changed to a Libyan ports company (LPC) after its role and function were limited in 2006 only to port operations, and the role of port authority was given to LMA. Having different public entities with different and sometimes conflicting interests reporting to the same national level, and forced to cooperate in the same working environment, has caused serious management difficulties.

Misurata port is an autonomous port, it is owned, managed and operated by the Misurata Free Zone Company (MFZ). The port ownership was transferred to MFZ in 2006, whereas only port state control remains with the LMA. MFZ is a government company, which has its own budget and reports to the economics ministry, and has succeeded in making Misurata port as the Libyan first top port (Elferjani, 2015). This was seen most obviously in the cargo volume handled by the port compared to other Libyan ports (Zaroog and Westcott, 2014). Libyan ports have seen a rise in the number of ships calling at them from 2009 to 2014 except 2011 when the revolution against the Qaddafi regime took place. The port of Misurata had the highest number of these calls while, in 2011, the year of revolution, the port was closed to international navigation as the city of Misurata was under embargo of Qaddafi military forces.

### **Misurata Free Zone Port**

Misurata port is situated on the Northeastern shores of Libya 210 km from the capital Tripoli. The port is located in the city of Misurata, which is accounted for as an economic and commercial centre in the country. The port has a large hinterland and good access to the land transport network. The port has a total area of 360 hectares. There are about 60 hectares of open storage area and 67,500 square meters of covered storage warehouses. The port has 19 berths with a total quay length of 4,150 meters at depths ranging between 11 and 14 meters. There are new berths (17, 18, 19 and 20) still under construction. The port is designed with a total throughput capacity of 6 million tonnes per annum; which could be increased to ten million tonnes annually following future development. The port also has a grain tower with a storage capacity of 40,000 tons. Misurata Free Zone Port is the most modern port in the country (Oxford Business Group, 2009). It has been ranked, as the best operated Libyan seaports and has attracted many international transport lines (Esahiri, 2015). Also, its market share is more than 50% of the throughput of all Libyan ports (Esahiri, 2015). Table 1 shows the number of ships calling at the port of Misurata in

the past ten years, with the highest number of ships calling in 2009 and zero calling in 2011 the year of the Libyan revolution.

**Table 1: Ships calling at port Misurata in the last ten years**

Years	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Ships calls	1042	1160	1253	2031	1805	0	1270	1451	1249	933

The berths of Misurata port are divided into six categories based on the type of cargo that is handled at the berth see Table 2 and Figure 1.

**Table 2: Categorisation of berths at Misurata port and description of the Layout.**

Cargo type	Container	Cars	Bulk	Fuel	Animal	General cargo
Berth numbers	10, 10A, 11, 11A, 12, 13, 14	6, 15 16	3, 4, 5	26	1	2, 7, 8, 9

**Figure 1: Misurata port layout.**



### Ship waiting times (The case of Misurata port)

The congestion problem at Misurata port was modelled as a Multi-Server queuing problem with 19 berths which currently operate at the port and based on ship waiting times. The service pattern is on a First Come First Service (FCTS) priority rules and ships' arrival are open-ended. Thirty-six calendar months for three years 2013, 2014 and 2015 actual data

on arrivals, berthing, and departures of ships to and from Misurata port are considered. Table 3 reports percentage breakdown of shipping movements in the port of Misurata over the three years and according to cargo type. Most of the ships calling at the port are carrying container cargo and those ships more or less represent around half of ships' movement in the port. These percentages represent ships' movements according to cargo type not the quantity of the cargo itself.

**Table 3: Breakdown of the percentage of shipping movement in Misurata Port**

<b>Cargo Type</b>	<b>2013</b>	<b>2014</b>	<b>2015</b>	<b>Grand Total</b>
Container/RoRo	42.7%	44.7%	40.5%	42.8%
GENERAL CARGO	36.2%	27.7%	25.8%	30.5%
Fuel	9.0%	12.1%	11.5%	10.7%
Livestock carrier	5.1%	7.0%	9.6%	6.9%
Bulk Carrier	4.4%	7.1%	8.6%	6.5%
Vehicles carrier	2.5%	1.5%	4.0%	2.5%

Table 4 reports average and volatility for the waiting time for vessels in the port. The maximum value of the average ship waiting time in the port was in 2013, while the maximum value of the standard deviation for ships waiting time was in 2014. This indicates that, although 2013 is considered the most congested year for the port, it looks like serious bottlenecks in port operations caused high variations in ships waiting time in 2014. These variations in vessels average waiting time might be due to the fact that the traffic intensity in 2013 was steady, while in 2014 traffic intensity was more volatile. However, if the traffic intensity remained more or less the same over these two years, another argument could be a reduction in port operational efficiency in 2014.

**Table 4: Average and volatility of waiting time for different cargo types**

<b>Type of Vessel by Cargo</b>	<b>2013</b>		<b>2014</b>		<b>2015</b>		<b>Long-Term Trend</b>	
	<b>Average</b>	<b>SD</b>	<b>Average</b>	<b>SD</b>	<b>Average</b>	<b>SD</b>	<b>Average</b>	<b>SD</b>
Bulk Carrier	135:59:52	115:55:47	276:58:58	191:22:30	107:11:45	67:14:50	202:01:20	127:48:40
Fuel	36:35:48	33:53:04	109:12:48	88:55:39	90:02:04	56:51:03	88:36:05	61:38:30
GENERAL CARGO	83:33:04	69:09:03	86:02:44	42:28:06	48:31:33	28:07:38	79:53:36	51:49:53
Vehicles carrier	89:11:06	67:29:12	28:51:00	37:56:57	16:10:33	13:55:34	62:45:01	39:52:00
Container/RoRo	71:11:38	53:41:44	47:29:45	28:16:03	21:17:39	10:48:08	56:44:17	34:02:03
Livestock carrier	10:06:31	9:17:41	7:12:57	5:40:32	8:13:52	7:13:10	8:35:28	7:17:13

## **Discussion and Analysis**

The main purpose of this study was to investigate the drivers of congestions in Libyan commercial ports post the Arab Spring, in doing so the study focused on port of the Misurata Free Zone as a case study. The main reason behind this choice is that the port is considered to be the top Libyan commercial port, handling more than 50 per cent of the total cargo going through Libyan ports in the recent years. The Port of Misurata as well as the other Libyan ports, have suffered from severe port congestion over the past ten years. The main Macro factors behind this congestion are due to the impact of the country's isolation during the Qaddafi regime period. All Libyan ports are state-owned enterprises and have suffered from the impact of centralization of the budget, and also the economic mismanagement of the rolling regime. This poor economic administration combined with the absence of private sector competition has led to less development and inefficient improvement in all transportation sectors, especially in ports. Moreover, the impact of closing Libyan oil fields at the beginning of 2014, resulted in the cutting of oil exports and an increase in the fiscal deficit. These factors made the economic situation worse, and any future plans for upgrading the Libyan ports will be hard to achieve.

The study also found that the port of Misurata has suffered from three types of port congestion: Ship working congestion, Ship berth congestion, and Cargo storing congestion. These types of congestion lead to ships waiting and queueing for berthing space. Empirical data suggest that the highest value for average ships waiting time was in 2013, when it increased along with the increasing in demand for the port service. However, the standard deviation of the average of ships waiting time had a greater value in 2014, even though in this year the cargo flow through the port decreased compared to 2013. These figures suggest inefficiency in port operations and poor port productivity especially in 2014. Furthermore, the study tried to look at the main causes of these types of port congestion at a micro level. It was found that the shortage of equipment spare parts, and poor maintenance for quayside facilities coincided with unqualified staff and the absence of good management and ship-berth allocation planning. Also, the strong Labour Union in the port creates a real impediment and hinders the port management from planning and improving the port operation productivity.

In order to solve the port congestion in Misurata port, crucial steps need to be taken at two levels. Firstly, the highest level of the Libyan government should give more attention to the ports sector and create for them some free 'space' to set their own rules and Tariff policies. Moreover and after the political situation settles down, the government should gradually allow the private sector to participate in managing and operating the ports, and should take serious steps to deregulate the port labour system in order to reduce the



dominance of Labour Union in the ports. In addition, the congestion problem in Misurata port is not related to an inadequate of the number of berths, it is more closely related to the inefficiency of port operations, and poor port management coupled with a bad organization. Thus the second step to solve port congestion at Misurata port should be at the port management level where the management should be aware of their responsibilities to improve their port service efficiency and should increase efforts to improve port productivity. This improvement could, for example, include training their staff, providing the port with high-tech facilities and keeping the port operational through improved maintenance and repair. Further the port requires qualified and experienced people who are able to achieve improved ship-berth allocation planning outcomes.

## ACKNOWLEDGMENTS

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# THE IMPACT OF MACROECONOMIC INDICATORS ON FORECASTING A TOTAL CARGO THROUGHPUT IN THE ADRIATIC SEAPORT

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## ABSTRACT

The paper addresses a decision support system for forecasting a total cargo throughput in the Port of Koper. The system is based on the combination of dynamic factor model (DFM) and ARIMAX time series model. The DFM extracts useful information obtained from the exogenous macroeconomic indicators. The dynamic factors are afterward directed into the ARIMAX forecasting model, which predicts a future behavior of the total cargo. The modeling design that consists of four stages has been used to obtain the final selected DFM-ARIMAX model. The results show that the forecasting system can predict well the observed throughput. Thus, it might serve as a useful reinforcement of an existing decision support system.

## 1. INTRODUCTION

Nowadays, it is essential to assure a valuable forecasting decision support system (FDSS) for predicting a future cargo throughput in seaports. High forecasting accuracy can essentially impact on the proper strategy for future infrastructure based investments, port development, and an efficient daily management [1]. The paper investigates the impact of macroeconomic indicators on the forecasting total cargo throughput time series in the observed Adriatic seaport (Port of Koper, Slovenia). The main aim is to build a forecasting model which would provide additional support to the existing FDSS system. The research introduced here represents a continuation of our previous research [2], where the container throughput forecasting has been conducted while using different methodological approaches to reduce the dimension of input (exogenous) macroeconomic variables.

The conceptual framework of our research is presented in figure 1. Comparing to the research [2], several improvements have been conducted in the modeling process. As can be seen from figure 1, four main stages have been applied. In this context, the constructed forecasting system comprises two basic methodologies, the dynamic factor analysis (DFA) [3] and the Box-Jenkins (BJ) time series modeling approach, where the ARIMAX model (Auto-Regressive Integrated Moving-Average model with Exogenous inputs) [4] has been used. In the first stage, the DFA extracts relevant information from a huge amount of the standardized values  $z_k(t), k=1, \dots, 54$  of the observed external

macroeconomic indicators  $x_k(t), k=1, \dots, 54$ . As macroeconomic indicators, the GDP per capita, purchasing power parity (PPP), import, and export were considered. The latter were observed in the context of four geographic areas: the hinterland countries, EU countries, the entire World, and the major Far-East Asian exporters. This constellation has given us the total number of 54 applied economic indicators (see figure 1).

In the second stage, the much lower number of derived dynamic factors  $u_i(t)$  is conducted into the modeling procedure, which calculates the most appropriate ARIMAX forecasting model for predicting the future behavior of the observed time series  $y(t)$ . In the modeling process, the whole family of ARIMAX models of different orders is created, and for each of them, the parameters are estimated (stage 2). In the third stage, the diagnostic checking is conducted, and goodness of fit (GOF) measures are calculated for each model candidate. During the model selection process, employed in the fourth stage, a special heuristic is developed to find the best model among many model candidates. For this purpose, various statistical and information criteria and predefined rules for each model candidate are also applied. Such heuristic gives us the final ARIMAX model, which can be considered as the best one. As it turns out, the derived model effectively reveals the impact of economic indicators  $x_k(t)$  on the total cargo throughput's forecasts  $\hat{y}(t)$ .

Moreover, the applied heuristic procedure also gives such model that is capable of making fairly accurate forecasts  $\hat{y}(t)$  of the future total cargo throughput trends. Further, besides providing the well model's fit to the real data  $y(t)$ , the constructed model satisfies all other rigorous mathematical and statistical conditions, such as those related to the invertibility, stationarity, and stability issues as well. Finally, the most influential economic indicators  $x_k(t)$  have been quite appropriately incorporated into the model via the use of dynamic factors  $u_i(t)$ .

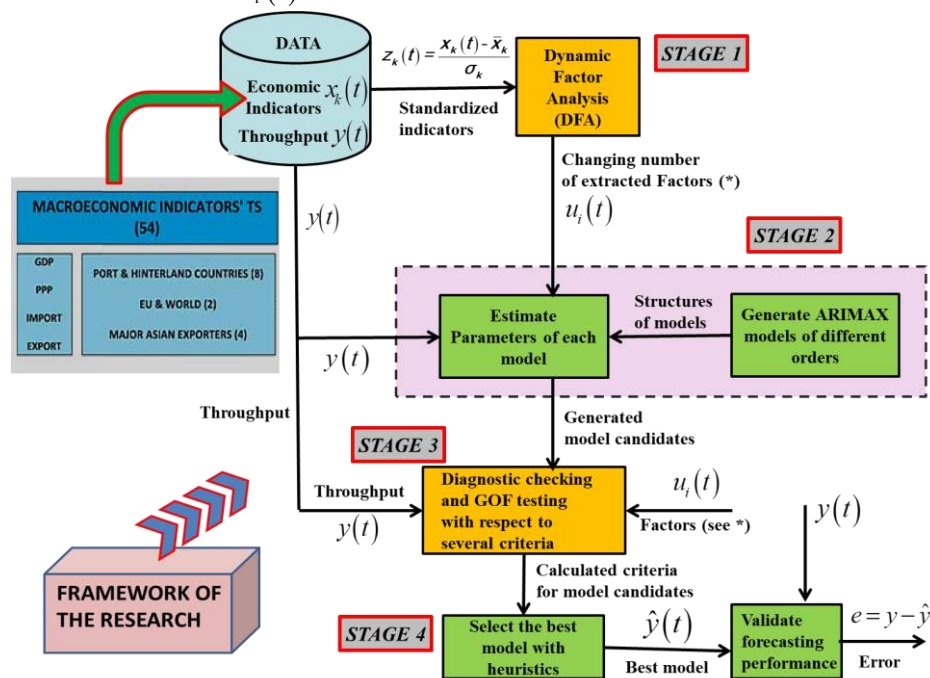


Figure 1: The conceptual framework of the complete research.

The presented framework offers encouraging prediction results regarding the total cargo throughput. Hopefully, the future research will lead us to similarly successful forecasting results for the other main cargo types. Thus, the overall developed FDSS system might have been a valuable reinforcement of the existing decision support system in the port. Moreover, the proposed framework would likely be useful for the other similar ports as well, meaning not only for those located in the Adriatic Sea but also for the others in the

Mediterranean Sea. Besides the possible applicative-based contribution, we believe that our study also has the following main contributions:

1. There are not many similar studies detected, which would comprise so many exogenous economic indicators in the field of throughput forecasting, as it has been conducted in our research.
2. To the best of our knowledge, there are practically no comparable throughput forecasting studies recognized, which would present such kind of modeling framework, as it was proposed in our prototype FDSS.
3. The novel heuristic procedure, which was used during the model selection procedure, is fundamentally different from those detected in other similar studies from the field.

## **2. LITERATURE REVIEW**

### **2.1 Port throughput forecasting approaches**

Port Throughput forecasting is an attractive scientific field, and whole spectra of papers have been written on this topic. Forecasting models were constructed for many ports worldwide by applying various modeling approaches.

Several authors have conducted a Box-Jenkins methodology. For instance, [5] have introduced an ARIMA modeling approach to capture the dynamics of maritime flows in the Suez Canal. On the other side, [1, 6] have used a similar approach, but with an additional seasonal component considered (SARIMA model). In the work of [7], ARIMA and SARIMA models were combined with the least squares support vector regression to forecast the throughput of two Chinese ports.

Some papers have also reported the results of comprehensive comparative studies regarding a performance of several prediction models [1, 8, 9]. For instance, in work [1], the following forecasting models have been compared: the regression model with seasonal dummy variables, the classical decomposition model, the trigonometric regression model, the SARIMA model, the gray model, and the hybrid gray model.

Besides the aforementioned classical approaches, some researchers have also applied models based on artificial intelligence and statistical learning theory. A typical example of such study is the paper [10], where the back propagation artificial neural networks (ANN) were used to predict the Guangdong port's throughput. Here, the genetic algorithms (GA) were also conducted, and the different influential macroeconomic factors were observed. On the other side, [11] introduced a combined modeling framework with a regression model and additional GA procedure to predict the container throughput of Qingdao port.

Some other approaches, which have also been detected in the existing literature, include the following methodologies [12]: nonlinear time series modeling, state space modeling, error-correction modeling, advanced econometric modeling, chaos theory, emerging systems and automata, and so on.

### **2.2 Inclusion of external exogenous effects**

Many scholars have reported that the incorporation of exogenous macroeconomic indicators into the prediction models can lead to a significantly better forecasting performance [13, 14]. The following indicators are usually most suitable to be applied as model's inputs: volume of import/export cargo, production and population determinants, and different types of Gross Domestic Product (GDP).

Regarding the cargo throughput in ports, a typical study that includes the external effects is those of [15]. Here, a multiple linear regression model was applied to identify the impact of various economic factors on the forecasted cargo throughput in the Port of Hong Kong. Similarly, a linear regression model was employed in [16], where the future volumes of Taiwan's import containers were estimated.

However, an identification of external variables that truly influence on the predicted throughput is not an easy task. Moreover, in the case of a large number of exogenous inputs, additional problems can arise related to the high dimensionality and possible multicollinearity [17]. In such cases, the dimensionality reduction techniques such as principal components analysis (PCA) and the DFA might be very convenient to use.

The DFA is designed in the sense of catching the cross-sectional dynamics between the external exogenous variables, afterward reflected in a significantly smaller number of the common dynamic factors [18]. During the last 15 years, many successful DFA studies have arisen in the different research areas due to rapid improvement of a computational power of computers. Yet more, the DFM models have recently been even enriched with more progressive estimation techniques [18]. Their success can be investigated in many contributions, such as [14, 19-23].

### 3. THE PORT OF KOPER THROUGHPUT AND THE LEADING INDICATORS

The Slovenian Port of Koper is a modern, well equipped and well organized multipurpose hub, located on the south coast of the Gulf of Trieste. It has 11 specialized terminals for different types of goods, while the port area spreads along a total quay length more than 3.300 meters wide. The port is specialized for the following principal types of cargo: Liquid bulk, Solid bulk, General Cargo, Containers, RO-RO, and the Total cargo [24].

The port provides various types of logistics services related to cargo handling or warehousing, as well as many other customer support oriented services. Since the port has been recording a continuous growth of the cargo volumes during the past decades, it has taken a role of the quite important regional competitor. The port is also a member of North Adriatic Ports Association (NAPA)<sup>1</sup> [24]. Since the NAPA ports have an exceptionally suitable location in the northern corner of the Adriatic Sea, they provide a seaway that enters quite deeply into the South-East edge of the European continent. Accordingly, the sea route from the Far East via Suez Canal to Europe is approximately 2.000 nautical miles shorter than in the case of rival North-European ports [24].

#### 3.1 A Time series of the Total Cargo Throughput

Regarding the total cargo throughput, the latter refers to the aggregation of all the major cargo type volumes. We have included it in our research because it is quite important in the context of the entire decision-making process of the planning of future port activities. For this throughput, we have observed its time series in the time domain from the year 2001 to the year 2014. This way, we have obtained a sequence of  $M=56$  quarterly observations based on the port's annual reports and one of our previous reports i.e. [24]. Figure 2 shows the observed time series  $y(t)$ , where the data are measured in ktonnes.

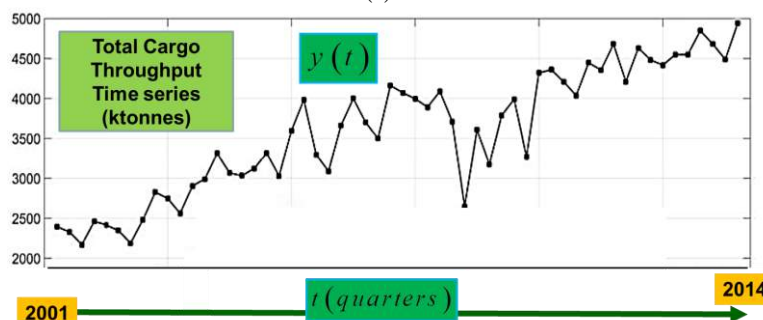


Figure 2: The observed quarterly time series in ktonnes measured over a time horizon 2001-2014 (56-time observations).

#### 3.2 Applied Macroeconomic indicators

In our study, the economic phenomena, which are supposed to affect the most on the port's throughput dynamics, can be looked at two different aspects (macroeconomic and geographical aspect). The first aspect concerns the different types of selected macroeconomic indicators. At this point, we have applied the following important indicator types (see figure 1):

- The percentage of change in the value of **gross domestic product (GDP per capita)**;

<sup>1</sup> Other NAPA ports are: Venice (Italy), Trieste (Italy), and Rijeka (Croatia).

- The purchasing power parity (**PPP**);
- The **Import's** indicator (in  $10^9$  US dollars); and
- The **Export's** indicator (in  $10^9$  US dollars).

The second, geographical aspect reflects the selected countries or regions, for which the aforementioned economic indicators were acquired. For this purpose, we have classified and applied the following different geographical scales:

- The **local scale** (the port's country *Slovenia* and its hinterland countries: *Italy, Croatia, Austria, Czech Republic, Germany, Hungary, Slovakia*);
- The **regional scale** (*EU*);
- The **global scale** (*Entire World*);
- The **major Far-East Asian exporters** (*China, Japan, South Korea, Singapore*).

By applying both classifications mentioned above regarding the four indicator types and 14 geographical entities, the total number of  $N=54$  different macroeconomic time series have occurred (the PPP is not listed for the EU and the World). The corresponding data were collected by the means of [25-29]. To timely synchronize them with the observed total cargo throughput, the same time-period was considered (from 2001 to 2014). Since the macroeconomic time series were listed only on the annual or monthly scale, we have also divided them into quarters. This way, we have obtained equally long sequences of 56 observations as in the case of the total cargo throughput.

#### 4. THE USED METHODOLOGY AND MODELING DESIGN

The conceptual framework of the proposed forecasting decision support system has been introduced in figure 1. In general, it comprises the following three concepts applied for the modeling purposes:

- 1. The DFA;
- 2. The ARIMAX models' generating procedure; and
- 3. The model selection framework (to find the most appropriate model).

While doing the DFA, the external indicators are reduced to some lower level of dynamic factors that retain the essential information about mutual co-movement of original exogenous variables. The extracted factors are in the next step injected into the ARIMAX models' generating mechanism. The latter builds an entire family of model candidates of different orders, dependent on the changing value of input delay, output delay, and noise delay [30]. Each ARIMAX model candidate reflects the predicted dynamics of the throughput time series at its output that is dependent on the dynamics of the model's input variables (factors).

The central part of the FDSS is a model selection mechanism, which integrates the DFA and ARIMAX modeling procedures into the unique framework. It consists of several consecutive steps that lead us to the most appropriate ARIMAX model. These steps employ the whole plethora of various statistical, information-based, and residual-based criteria, which help us to find the final model by means of the particular heuristic.

##### 4.1 The Dynamic Factor Analysis

In the DFA, the time-dependent dynamic factors are applied to reconstruct the exogenous time series' common trends, for which the interactive effects must be captured [31]. Here, the number of factors  $m \ll N=54$  is selected a priori, while the original time series  $x_k(t)$  are usually standardized (see figure 1).

Besides the extraction of dynamic factors denoted by  $u_i(t)$ ,  $i=1,...,m, t=1,...,M$ , the DFA also estimates the factor loadings, which signify the strength of the relationship between the original time series and the corresponding factors [18]. The composition of dynamic factors and factor loadings represents a dynamic factor model (DFM), which contains so-called hyper-parameters and is identified in a vector-matrix state space form [32]).

The hyper-parameters of the DFM are estimated by combining the state-space model formulation with the maximum-likelihood (ML) estimation method [32]. The ML method can be conducted by means of the recursive expectation-maximization (EM) algorithm [33]. In the expectation step (E-step), the Kalman filter or smoother is

employed to estimate the unknown parameters. Afterward, in the maximization step (M-step), the estimated parameters are updated. This way, the EM algorithm iteratively alternates between both steps until the convergence to the adequate values of estimated hyper-parameters is reached [34].

## 4.2 The ARIMAX Modeling Framework

The ARIMAX model represents the composition of the following parts:

- 1. The autoregressive (AR) part of the output time series denoted by  $y(t)$ ,
- 2. The moving average (MA) fragment,
- 3. The integrated (I) component, and
- 4. The exogenous inputs' component (X), in our case the dynamic factors  $u_i(t)$ .

The first two parts refer to the dependence of the current stationary observation from its past observations and past values of random errors, respectively [35]. The integrated part I must be included when the time series  $y(t)$  is not stationary. In such cases, the differencing procedure should be conducted to convert the original non-stationary time series into its stationary equivalent. Finally, the exogenous component X presents a supplementary incorporation of present and past values of exogenous inputs  $u_i(t)$  into the ARIMAX model [36].

In the sequel, we are going to introduce the structure of ARMAX model (ARIMAX without I part). Since we are dealing with the multiple inputs-single output (MISO) model, the ARMAX transfer function model representation can be given by equation (1) [30]:

$$A(q) \cdot y(t) = \sum_{i=1}^m B_i(q) \cdot u_i(t) + C(q) \cdot \varepsilon(t) \quad (1)$$

where  $A(q)$ ,  $B_i(q)$  and  $C(q)$  represent the following polynomial functions (equations (2)):

$$\begin{aligned} A(q) &= 1 + a_1 \cdot q^{-1} + \dots + a_{n_a} \cdot q^{-n_a} \\ B_i(q) &= b_{0i} + b_{1i} \cdot q^{-1} + \dots + b_{n_{b_i}} \cdot q^{-n_{b_i}} \quad i = 1, 2, \dots, m \\ C(q) &= 1 + c_1 \cdot q^{-1} + \dots + c_{n_c} \cdot q^{-n_c} \end{aligned} \quad (2)$$

Here,  $A(q)$  shifts output values  $y(t)$  into the past by means of backshift operator  $q^{-1}$ . Similarly, the polynomial functions  $B_i(q)$  shift the exogenous inputs  $u_i(t)$  into the past, while the function  $C(q)$  reflects the present and past values of the noise term  $\varepsilon(t)$ . The latter is assumed to have the properties similar those of the white noise. The order  $n_a$  defines the oldest delay, which still has an impact on the output  $y(t)$ . Similarly, the orders  $n_{b_i}$  determine the oldest delays of the inputs  $u_i(t)$ , while the order  $n_c$  denotes the oldest delay of the noise term  $\varepsilon(t)$ . The parameters  $a_i$ ,  $b_j$  and  $c_k$  refer to the model's output parameters, input parameters, and noise parameters, respectively.

The ARIMAX model has a quite similar structure as those presented in expression (1) for the ARMAX model, except that we must replace the output  $y(t)$  with its single differentiated equivalent  $\Delta y(t) = y(t) - y(t-1)$ . In our case, it turns out that only the first order of differencing is needed to obtain the stationary throughput time series.

## 4.3 The deeper insight into the modeling process

Before the beginning of the of the entire modeling process in figure 1, the stationarity of the observed time series was tested by means of unit root tests. At this point, the Augmented Dickey-Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests were applied. On their basis, it was discovered that the ARIMAX model with the first differences' operator should be used for the fit to the real data.

While executing the DFA analysis (see figure 1), several different dynamic factor models with a different number of dynamic factors ( $m=1,\dots,m_{\max}=5$ ) have been generated. For each DFM, the EM algorithm was used to estimate the most appropriate model's hyperparameters. The reason why we have applied several different DFMs is that we wanted to investigate which DFM model contains the dynamic factors with the most informative content kept from the original exogenous variables.

Subsequently, the entire family of ARIMAX model candidates was generated for each possible number ( $i=1,\dots,m \in \{1,\dots,m_{\max}=5\}$ ) of previously extracted dynamic factors.

Moreover, for the each  $i=1,\dots,m$ , at a given number of the dynamic factors, we have used a different setting i.e. the different combinations of input, output and noise delays' orders of the ARIMAX model. These orders had been gradually increasing from value 1 up to their most appropriate maximum value, which has turned out to be:  $(n_{a_{\max}}=n_{bi_{\max}}=n_{c_{\max}}=4)$ .

Thus, while proceeding these calculations, one model candidate was generated for each combination of the modeling process at this stage. Further, after the completion of all such calculations, the entire family of several hundred of different ARIMAX models has been created. Since we did not only create the structures of model candidates but also estimated the models' parameters as well, the modeling process has required quite a significant computational effort.

Within the scope of calculating the diagnostic checking measures, a numerous statistical, information-based, and residual-based criteria were calculated to validate the statistical properties, performance, and goodness of fit of each model candidate. Here, the following criteria and measures have been calculated for every single candidate [35]:

- The mean absolute estimation (MAE);
- The root mean square error (RMSE);
- The percentage of model's fit (FIT); and
- The information Akaike's corrected AICc criteria.

Further, the Portmanteu (Ljung-Box) LB test, as well as the Jarque-Bera (JB) test [35] have been conducted to examine whether the model's residual possess the properties of the white noise without any severe serial correlation. Also, the algorithm at this point calculated the significance level of the model's parameters, as well as investigated the model's transfer function zeros and poles.

When the modeling process has entered into the last, fourth stage, the final model selection has been carried out by means of the applied heuristic procedure. Here, the radical reduction of the previously generated set of candidate models has been conducted at first. Each candidate of the set has been exposed to the statistical testing of the previously calculated diagnostic checking measures. The candidate was rejected or accepted on the basis of certain acceptance rules, for which it should have simultaneously possessed the several required characteristics, such as:

- The low values of MAE, RMSE and AICc with respect to a predefined threshold level;
- The high value of FIT;
- The residual shares the properties of the white noise (fulfilled JB and LB tests);
- The model should be parsimonious with as many significant parameters as possible;
- The model's transfer function's zeros and poles must all lie within the unit circle. In the case of this property fulfilled, the candidate has satisfied the conditions of stationarity, invertibility, and stability [4, 30].

Such process of the acceptance or rejection of the model candidates has been carried out by using the heuristic procedure in a very systematic process of exposure of the model to the predefined sequence of acceptance rules conducted appropriately one after another. This way, the algorithm was able to reduce the initial set of the hundreds of candidates to only a few remaining candidates that passed all the rigorous tests. Afterward, in principle, the final model selection from the remaining set of the candidates is left to the FDSS user. However, in our case, we have carried out the final selection by choosing that model candidate, which has had the highest FIT measure. This way, we have obtained the most adequate forecasting model.



The developed FDSS framework was partly implemented in the technical computing environment MATLAB, and partly in the statistical computing environment R. The latter was used to carry out the DFA analysis using the MARSS package [37]. In the MATLAB, the ARIMAX models' generation and estimation were conducted by means of System Identification Toolbox [38]. On the other side, the statistical testing was processed using the two toolboxes, the Statistics and Machine Learning toolbox, and the Econometrics Toolbox. Finally, the entire mechanism of our modeling process, including the final model selection step, was merged together in the MATLAB basic environment.

## 5. THE NUMERICAL RESULTS

### 5.1 Transfer function structure of the derived model

The estimated transfer function's structure of the final model has the following form:

$$A(q) \cdot \Delta y(t) = \sum_{i=1}^5 B_i(q) \cdot u_i(t) + C(q) \cdot \varepsilon_y(t) \quad (3)$$

$$A(q) = 1 + \underbrace{0.48 \cdot q^{-1}}_{(2.4)} - \underbrace{0.25 \cdot q^{-3}}_{(-2.9)} \quad B_1(q) = \underbrace{742.95}_{(3.0)} + \underbrace{450.7 \cdot q^{-1}}_{(2.0)} \quad B_2(q) = \underbrace{34.66}_{(2.0)} - \underbrace{32.79 \cdot q^{-1}}_{(-2.2)}$$

$$B_3(q) = -\underbrace{49.1}_{(-2.8)} - \underbrace{33.01 \cdot q^{-2}}_{(-2.7)} \quad B_4(q) = \underbrace{306.4}_{(3.3)} \quad B_5(q) = \underbrace{3062}_{(3.6)} + \underbrace{1585 \cdot q^{-1}}_{(4.1)} - \underbrace{1090 \cdot q^{-2}}_{(-2.5)}$$

$$C(q) = 1 - \underbrace{0.64 \cdot q^{-1}}_{(-2.5)}$$

The values in parenthesis refer to the t-values of the estimated parameters, which were statistically significant at level 0.05. From the expression (3) we can see that we have excluded those predictors from our model, whose parameters were insignificant.

### 5.2 The predictive performance of the derived model

Figure 3 shows the prediction results of the derived model regarding the forecasts of the total cargo throughput. While estimating the models' parameters, we have used first 40-time samples, while latest 16-time samples were engaged in the process of validation of the models' predictive performance. As it turned out, the model has achieved (%FIT = 80.3), thus an 80.3% fit to the real data.

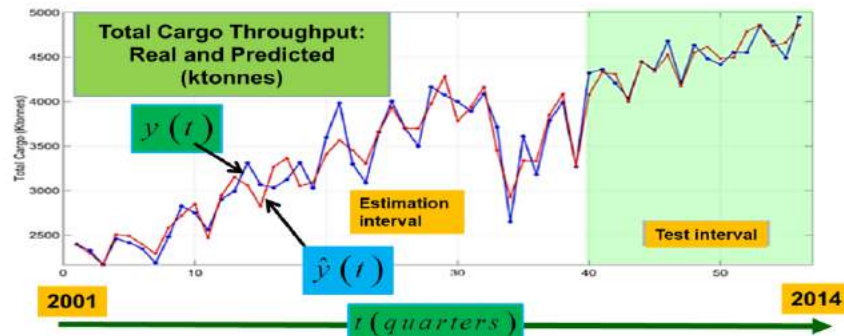


Figure 3: The prediction results of the derived model for the total cargo throughput:  $y(t)$  - the real time series;  $\hat{y}(t)$  - the predicted time series.

Based on these results we can conclude that the forecasting performance of the derived ARIMAX model enables us a fairly good fit to the real total cargo throughput data. It is true that there are some more sophisticated details of the dynamics identified that cannot be totally predicted by our final model. We believe that there exist two primary reasons for this fact: Firstly, the mechanisms that generate the observed time series, likely contain a significantly complex nature, which is hard or even impossible to be completely incorporated into our model; Secondly, the composition of all demanded criteria for the selection of the final model has been quite rigorous. Yet, despite this, the derived model provides a well-fit to the real data, particularly concerning the main movements of the time series' trends. In the end, it must be emphasized that we have also derived the models, which were able to achieve a significantly better fit to the data. However, the main deficiency of such models was that they were not parsimonious and

had too many insignificant parameters, or the problems have arisen regarding the model's poles/zeros, which were lying outside the unit circle.

## CONCLUSION

In this paper, we have developed a prototyping forecasting module to predict the total cargo in the Port of Koper. For this purpose, the four-stage modeling design was introduced that has combined two different modeling approaches, the dynamic factor analysis, and the ARIMAX modeling process.

In the first stage, the DFA analysis helped us in reducing a large number of influential macroeconomic time series to much lower number of corresponding dynamic factors. The latter were afterward injected as inputs into the ARIMAX modeling design process. Here, the three stages followed: the construction of different ARIMAX model candidates, the calculation of various criteria for each model candidate, and finally, the selection of the most appropriate model. The final model selection was carried out by a systematic use of the heuristic procedure that has excluded those candidates that did not satisfy the previously calculated criteria and predefined rules. The applied modeling procedure has shown to be effective not only in supporting the model's fit and information criteria, but also simultaneously in satisfying the other rigorous conditions, such as those related to the stationarity, invertibility, and stability issues.

While conducting the exogenous variables into the modeling process, the following macroeconomic indicators have been used: the GDP, export, import and the PPP. These indicators were observed for four different geographical regions (the hinterland countries, the EU, the World, and the major Asian exporters). The derived final selected model has provided quite promising prediction results, particularly concerning the main trend's movements. As it turned out, it achieved even an 80.3% fit to the real time series data.

In the future work, it is planned to expand the prediction range of the proposed model in such manner that it will be able to make forecasts for a wider i.e. medium-term future horizon as well. This way, we will hopefully positively contribute to the correctness of the medium-term decisions of the port's managers about the future planning of port operations. Moreover, in order to improve the predictive power and applicability of the proposed modeling framework, it is also intended to conduct some improvements. They include additional statistical tests for investigating of seasonality, nonlinearity, intervention, and other possible effects, which might have also been influential in the observed total cargo time series. Moreover, it is also planned to apply the proposed modeling framework to forecast the throughput of other types of cargo.

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# **THE DEVELOPMENT OF MODALSHIFT WITH SUPPLY CHAIN REFORM: A CASE STUDY OF JAPAN**

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## **ABSTRACT**

Although it is necessary to change the modes of transportation from truck to rail and ship for greener logistics, the convenience and low cost of truck has prevented companies from achieving this modal shift. However, recent trends have elevated awareness of the need for a modal shift because of a severe shortage of truck drivers. This paper investigates recent efforts to introduce modal shift led by shippers. In particular, it considers supply chain restructuring activities introduced by some companies, analysing specific examples of modal shift and tries to clarify the likely direction these efforts may take. Companies that ship large volumes of merchandise are starting to take the lead, often collaborating with other similar companies to re-evaluate the production and delivery structures of their supply chains. This is beginning to bring about a new modal shift. The key is to broaden the scope of the modal shift, and leverage the opportunity to optimize the entire supply chain.

## **FOREWORD**

In order to reduce the environmental impact of distribution systems, it is increasingly important to shift the mode of transportation used in delivering goods, from trucks to alternative means including rail and ship transport. In Japan, the government has introduced measures to encourage this modal shift, including subsidies. But for reasons of convenience and transport cost, truck deliveries continue to be a predominant method of delivering goods. There has yet to be a substantial shift in modes of transportation.

On the other hand, there have been major changes in the truck transportation business, recently. Transport companies face a severe shortage of drivers. Since 2015, the number of job openings for truck drivers has averaged twice the number of drivers seeking jobs. Despite concerted efforts to attract workers, companies are still unable to fill all the positions, and the labor shortage continues. Without enough qualified drivers, truck transportation has become less reliable, and rates are rising.

Due to the worsening shortage of drivers, truck transport has become less reliable, and with fees rising, the importance of pursuing a modal shift is increasingly recognized. This seems to be accelerating the modal shift, and introducing new characteristics to the process. Specifically, companies which have merchandise to transport or deliver are now beginning to take the initiative, cooperating with their industry peers to make changes to their supply chain and promote the shift to alternate modes of transportation.

In this paper, we will examine the recent increase in collaboration between multiple product suppliers and manufacturers, working together to promote a modal shift. In particular, we have identified and analyzed recent examples of collaboration among multiple product suppliers, and their steps to form consortia in order to restructure their supply chains through a modal shift. In this paper we offer examples, and analyze recent trends in the modal shift through surveys and interviews with companies involved in these efforts.

## **PROMOTING THE MODAL SHIFT**

Breaking down the current modal balance in Japan's transportation industry, on the basis of ton-kilometers of merchandise delivered, trucks account for 54.9% of total transportation, seaborne shipping accounts for 40.3%, and rail accounts for 4.6%. These figures illustrate the need to reduce the heavy dependence on trucks, shifting some cargo to rail container and regular-route coastal ship transport.

In Japan, a modal shift is considered effective when goods are transported over distances exceeding 500 km. The busiest traffic corridor for cargo transport in Japan is the Tokyo-Osaka route, which is a distance of roughly 500 km. Over distances exceeding this level, rail transport or ship transport is more effective than trucking.

One characteristic of rail cargo transport in Japan is that it uses rail containers measuring 12 feet in length and with a 5 tonne capacity. These smaller containers are unique to Japan, and are used by most rail container transport services in the country. Comparatively few rail services handle the standard international freight containers used by sea transport companies. This is because most railyards that handle cargo do not have equipment that can handle the larger, 40-foot containers that are used by most international container ships. Furthermore, most rail tunnels have ceilings that are too low to accommodate high cube containers. These physical limitations are a difficult barrier to overcome.

As for waterborne transportation, ferry services play a key role in the transport network. However, in 2009 the tolls for trucks making nighttime use of domestic expressways were reduced dramatically, and as a result there was a sharp drop in the volume of trucks using roll-on, roll-off ferry services. This drop in traffic prompted some operators to suspend such ferry services altogether. More recently, though, the shortage of truck drivers has prompted a recovery in truck use of ferry services, as operators try to reduce the need for truckers to drive time-consuming, long-haul routes. In 2016, ferry service operators even began to introduce new ferry routes and to purchase new vessels, expanding their transport capacity.

The government, meanwhile, has introduced measures to encourage companies to conserve energy. The Energy Conservation Act was a first step in this direction, but revisions to this law and transport-industry regulations have since been introduced in order to further promote environment-friendly distribution systems. Such regulations require not only transportation companies, but also those who ship products, to take steps to cut energy consumption.

One regulation in particular requires companies that ship large volumes of goods – defined as “specified consigners” (those who ship over 30 million tonne/km of goods per year) – to formulate energy conservation plans and to submit reports on these plans on a regular basis. Similarly, all transportation companies that own and operate over 200 trucks, as well as those that handle a substantial amount of rail, sea or air transport – defined as “specified carriers” – to formulate their own energy conservation plans, and submit reports on these efforts, regularly.

Both specified consigners and specified carriers must provide data on their CO<sub>2</sub> output per tonne/km of goods transported. As a target, they are expected to reduce this value by 1% per annum. One recommendation that is offered as a specific way to meet this target is a modal shift. Thus, although the regulations are aimed at cutting energy consumption, they are also helping to promote a modal shift. The government is also offering subsidies, commendations and other benefits to encourage companies to collaborate on measures that will help promote a modal shift.

## **STUDY OF MODAL SHIFT EXAMPLE – COOPERATIVE EFFORTS BY CONSIGNERS**

There has been a recent revival in awareness of the modal shift, and an increase in efforts to promote such a shift. One characteristic of this new trend is that the initiative is coming

from companies which ship large volumes of merchandise (consigners), and that many such companies are joining forces to achieve a modal shift. Below, we examine five examples of such efforts to promote a modal shift.

### **Cooperation by retailers and suppliers to promote a modal shift (Case A)**

One feature of traditional Japanese business practices is that product manufacturers or suppliers generally have the responsibility for making arrangements to ship merchandise to the company that purchases the merchandise. In the retail industry, this means that it is not the retailer, but the company that supplies goods to a retailer, which selects the transportation method. Nevertheless, retailers are taking active steps to promote a modal shift in the supply chain that delivers merchandise to their stores.

ARCS Co., Ltd., a retail chain that operates some 60 supermarkets in Hokkaido, procures a large volume of merchandise from CGC Japan Co., Ltd. CGC Japan is a retail chain cooperative which supplies merchandise to 220 member companies nationwide, most of which operate supermarket chains. It makes joint deliveries to the stores of all its members. In the past, CGC Japan selected the transport method, delivering merchandise to customers by truck and/or ferry. However, noting the need to preserve the environment, ARCS asked CGC Japan to deliver the merchandise that it purchases using rail transport, thus achieving a modal shift in the distribution chain.

In the spring of 2015, ARCS introduced a trial system under which CGC delivered agricultural produce via rail. In 2016, as it expanded this rail transport program, ARCS took shipment of 300 five-tonne (12-foot) rail containers worth of merchandise.

In addition to taking shipments from CGC Japan via rail, ARCS took advantage of the fact that CGC Japan procures a large quantity of produce from farms in Hokkaido, and delivers it via long-distance transportation to stores in the greater Tokyo area. ARCS reached supply contracts with Hokkaido farmers under which it collected agricultural produce from local farms and dispatched it by rail to the CGC distribution centers in the Tokyo area. The delivery time from farm to retailer was almost the same as it was under the previous system, which used long-haul trucks, while delivery costs and CO<sub>2</sub> emissions were each reduced by 30%.

To accomplish the modal shift, it was necessary for ARCS, CGC Japan and a rail transport provider – Japan Freight Railway Co., to establish a consortium to oversee the details. This consortium holds regular meetings, about once a month, to identify the products to be shipped, and to evaluate the impact of introducing rail transportation. Recently, the consortium has been discussing ways to expand the use of rail transport, for example, by introducing refrigerated rail cargo containers in order to ensure the freshness of leaf vegetables, fish, meat and other perishable items.

### **Cooperation led by manufacturers to promote a modal shift (Case B)**

Some manufacturers have not only begun to distribute their own products via rail, but have begun promoting cooperation among manufacturers to create supply chains that can deliver parts from suppliers to the factory, as well as finished goods to market, thus expanding the scope of the modal shift.

For example, Toyota Motor Corporation began operating its own exclusive-use freight train, known as the “Toyota Long Pass Express”, to deliver auto parts between the company’s headquarters in Nagoya, and affiliated manufacturing plants in the Tohoku region, about 900 km away. This train is 20 cars long, and can handle up to 40 standard 31-foot containers, making two trips a day between Nagoya and Tohoku. The train not only carries auto parts manufactured by Toyota plants, but also handles parts and components made by other suppliers for use in Toyota vehicles. Looking at daily transport volume, the train carries about 600 cubic meters of Toyota auto parts, compared with 700 cubic meters

worth of parts supplied by other auto parts manufacturers. The volume of merchandise transported on behalf of suppliers is actually greater.

A large number of auto parts manufacturers have their production facilities in the vicinity of Nagoya, where Toyota's headquarters is located, and these facilities are quite a distance from Toyota's auto assembly plants in Tohoku, which they supply with components. Therefore, Toyota's train can collect auto parts from a number of suppliers and transport them in bulk to Tohoku. The fact that so many parts suppliers are concentrated in one region makes the train transport system even more effective.

Some 61.9% of the auto parts used by Toyota's assembly plant in Tohoku are transported to the factory by this container train. According to Toyota Motor, the use of the container train has actually reduced lead time compared with the situation when truck transport was used. It is also no more costly than truck transport, and reduces CO<sub>2</sub> emissions by an estimated 14,000 tonnes per year. One central characteristic of this example of a modal shift is that it was accomplished at the initiative of Toyota Motor, and achieved through Toyota's efforts to collect auto parts from its auto parts suppliers and transport them to the assembly plant by train.

### **Cooperation between industry peers to promote a modal shift (Case C)**

One interesting example of modal shift involves manufacturers whose products compete fiercely against one another in the marketplace, who nonetheless cooperate to jointly transport products by rail. The two largest beer manufacturers in Japan, top-ranked Kirin Brewery and number two manufacturer Asahi Breweries, are facing intensified competition in a domestic market that is gradually shrinking. At the same time, though, all manufacturers view pressure to reduce their transportation costs as an urgent issue. Consequently, the two companies teamed up in 2017 to begin transporting their beer products by rail container, in a joint distribution effort.

Both companies have large breweries located in the Osaka area. Trucks deliver beer from these factories to freight train depots in the vicinity. The products of both manufacturers are then loaded into containers and dispatched by rail to destinations in the Hokuriku region, over 300 km away.

The central characteristic of this example is that it involves a change in the location of the breweries which supply the Hokuriku region, in order to permit the beer to be dispatched by rail. Previously, markets in the Hokuriku region were supplied from breweries in Nagoya, which is closer to the final destination. The beer was transported from Nagoya to Hokuriku by truck. However, both companies faced a shortage of drivers, and this was pushing up the cost of beer delivery. The companies considered using rail transport from Nagoya to Hokuriku, but there was no spare container capacity available on the rail freight routes from Nagoya to Hokuriku, and the companies could not reserve space for their goods. Although the total rail distance from Osaka to Hokuriku was longer, there was space available on rail freight services. Therefore, the two companies decided to change the source of beer for Hokuriku markets to their Osaka factories, and transport their products by rail.

The current transport system operates 300 days per year, and allows the companies to dispatch up to 80 containers (each 12-foot container has a capacity of 5 tonnes) per day. This rail transport system replaces the equivalent of 10,000 trucks, and thus reduces CO<sub>2</sub> emissions by 2,700 tonnes per year.

### **Cooperation between manufacturers to promote a modal shift (Case D)**

Nearly all manufacturers in Japan face problems related to the shortage of truck drivers. Consequently, they are already cooperating to organize joint deliveries of merchandise to areas where transport efficiency is low. To expand cooperation in the area of logistics, many manufacturers are joining forces to set up long-distance transportation systems on

main routes. This example of modal shift is distinguished by the large number of manufacturers who cooperate in joint, trunk-line transport systems.

In 2016, six of Japan's largest manufacturers of processed foods – Ajinomoto, Kagome, Nissin OilliO Group, Nissin Foods, House Foods and Mizkan – began operating joint truck transport operations in Hokkaido. The joint operations allowed the companies to reduce the number of distribution centers from four to two, and all cooperating companies were able to utilize the same facilities for their products. Trucks dispatched from the centers carried products from all manufacturers. This greatly increased the capacity utilization of each truck, boosting efficiency and cutting CO<sub>2</sub> emissions by 15%.

In addition to this joint truck transportation system in Hokkaido, processed food manufacturers have introduced a modal shift in their long-distance transportation methods to the area, with joint deliveries of products to the local distribution centers. Four of the manufacturers have set up a system in which container trucks make the rounds of these companies' distribution centers in the Tokyo area, and dispatch the combined load of merchandise by container ship, to Hokkaido. These manufacturers are now expanding the joint system of transport to cover regions other than Hokkaido, with multiple manufacturers sending consignments of merchandise by rail, in shared containers, to achieve a modal shift.

In order to establish a more efficient and reliable supply chain for processed foods, the six major processed food manufacturers have created a distribution platform known as "F-LINE" (Food Logistics Intelligent NEtwork). F-LINE was created to handle the joint distribution of products for all six manufacturers on major, medium-distance transportation routes. F-LINE continues working to achieve the goals of unifying transport activities, considering modal shift possibilities and standardizing logistics.

#### **Joint efforts by disparate industries to promote a modal shift (Case E)**

Increasingly, retailers and manufacturers are working together to not only introduce a modal shift in the way that products are delivered from producer to retailer, but also to revise the transport methods used for purposes other than merchandise procurement.

AEON, Japan's largest retailing conglomerate, has been working aggressively to shift transportation of apparel and private brand merchandise to rail container systems. Their annual use of rail transport has been rising steadily, from the equivalent of 2,400 standard 5-tonne containers in 2008 to 18,000 in 2010. In an effort to expand this rail distribution system, the company started cooperating with manufacturers to organize joint rail transport. This succeeded in increasing transport volume to the equivalent of 37,000 containers in 2014.

To promote its cooperative rail transport efforts with manufacturers, AEON established the AEON Rail Transport Research Study Group. This organization not only studies ways to promote a modal shift in Aeon's procurement and distribution activities, but also ways in which cooperating manufacturers can accomplish a modal shift in their overall distribution efforts. In addition to transporting merchandise to AEON Group distribution centers, these efforts can help to increase the use of rail transport to deliver raw materials to factories, even if they have no direct ties to the AEON Group. The Group is therefore considering ways in which multiple manufacturers can organize joint, round trip transport systems by rail.

These discussions have already achieved some concrete results. For example, AEON teamed up with the beverage manufacturer Nestlé Japan to jointly transport cargoes by rail. On certain long-distance routes, a train will carry Nestlé products manufactured for AEON under a private brand supplier agreement, to AEON stores on one leg of the journey, and on the return leg it will carry products to other Nestlé customers which have no ties to AEON. In the same way, AEON has organized joint rail transport operations with Japan's



largest manufacturer of toiletries, Kao Corp., and the third-largest domestic brewery, Sapporo Breweries.

As other leading manufacturers join the AEON Rail Transport Study Group, the Group can promote a modal shift among many companies and industries with which AEON transacts business. At present, the Group includes 21 participating manufacturers and 10 transportation companies. Among the consumer products manufacturers which generate the most CO<sub>2</sub> emissions in Japan, 16 of the top 25 have become members of the Group. In this way, many of Japan's leading manufacturers are now actively considering ways to increase the use of rail transportation.

## **COCLUSIONS**

When corporations consider whether or not to shift their modes of transportation, they must take into consideration the cost and delivery time of each alternative distribution service. In the past, these considerations took place only at the stage of dispatching goods to a destination. Consequently, logistics operators were the ones with the greatest influence on promoting a modal shift. More recently, though, Japan has seen an increasing number of examples in which merchandise suppliers (consigners) have taken the initiative, or in which multiple companies have collaborated to achieve the shift in modes of transportation. There are three major factors underlying this trend.

First of all, the modal shift efforts in the past have all been strongly associated with the goal of environmental protection. More recently, however, other factors have come into play, such as the shortage of truck drivers, which has made it difficult for companies to guarantee the availability of transportation over medium- and long-distance routes, particularly during peak business periods. This has also pushed up trucking costs, making transportation expenses a very serious issue. This has given companies with large quantities of goods to transport a new impetus to consider changing the mode of transportation.

A second factor is the fact that companies are seeking various ways to improve the efficiency of their transport-related operations. There are limits to the efficiency that companies can achieve when they address the issue on their own. However, since they now recognize the importance of improving efficiency, companies are resolving this limitation by cooperating with one another, to develop joint transportation solutions.

A third factor is robust government support for the modal shift. The government offers a variety of incentives, subsidies and recognitions to companies that cooperate to achieve a modal shift in their distribution activities. At first, most efforts at achieving a modal shift were individual steps taken by a specific company, but nowadays there has been a greater focus on cooperation, with numerous companies setting up consortia which make continuing efforts to achieve the modal shift.

This paper considered five examples of cooperative activities, initiated by one or more companies with a large volume of goods to transport (consigners). In Figure 1, we have illustrated the supply chains for each of these five case studies, and noted the stage of the supply chain which has been addressed, to achieve a modal shift. In Case A, a retailer has revised the procurement activities in its supply chain in cooperation with vendors, to use rail transport. In Case B, a manufacturer and its parts suppliers are cooperating to transport parts and materials to the assembly plant by rail. Cases C and D illustrate how manufacturers can cooperate to jointly deliver products to multiple wholesalers and retailers, via rail and sea transportation. In Case E, a large number of companies, including both manufacturers and retailers, have set up a group that promotes the use of rail transport by all participating members. In this way, companies have found many ways to revise their supply chains and make the modal shift from truck transport to rail transport.

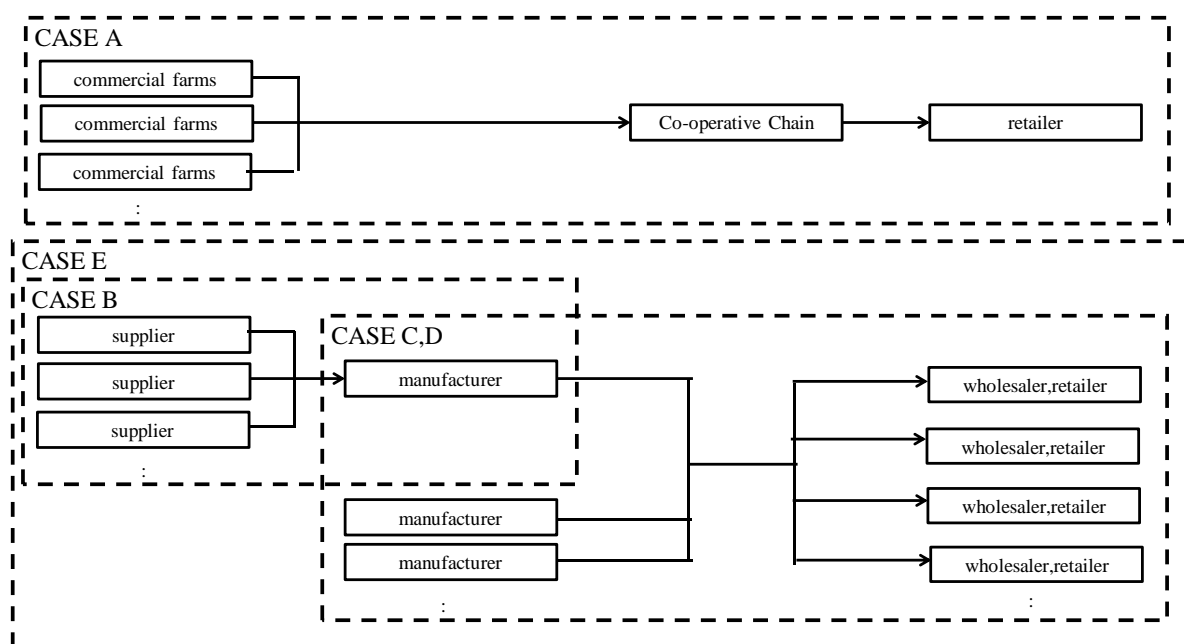


Figure 1. Portions of the supply chain covered by rail transport, in each case study

Table 1 summarizes the characteristics of rail transportation in each of the case studies. In Case A, rail transport is being used not only to procure merchandise for a retailer to sell, but also to use the rail cars on the return journey to ship produce to other retailers. Cases C and D involve joint use of rail transportation to ship merchandise back and forth on major, long-distance transportation routes, and then to local destinations. In Case C, in particular, the modal shift was accomplished by altering the structure of the supply chain, including a shift in the production site, in order to utilize rail transport. In Case E, manufacturers and retailers are collaborating to build complete supply chains, introducing rail transport wherever possible.

	Characteristics of rail use			Type of cargo transported by rail	Adjustment of production	Connection to other transport system	Details of rail transport system
	Private train	Type of containers	Round-trip				
Case A		5-tonne container	✖	Cargo within the supply chain			Continuous discussion among participants
Case B	✖	31-foot container		Cargo within the supply chain			Continuous discussion among participants
Case C		5-tonne container		Cargo within the supply chain	Change in production location	Connection to local joint distribution	Continuous discussion among participants
Case D		5-tonne container		Cargo within the supply chain		Connection to local joint distribution	Continuous discussion of ways to develop the joint distribution consortium
Case E	✖	5-tonne container 31-foot container	✖	All cargoes handled by Group participants			Continuous discussion among Group members of ways to utilize rail transport

Table 1. Characteristics of rail transport in each case study

Many efforts of this type involve the creation of consortia by multiple consigners, with the goal of achieving a modal shift in their supply chains, and are notable for the fact that there is an ongoing effort to consider further improvements. Participating companies seek ways to cooperate, meet regularly to consider new changes, exchange information, and explore ways in which their cooperative effort can not only help shift transport activity to rail, but also achieve improvements in overall efficiency.

As consigners take the lead in promoting a modal shift, and as they increasingly cooperate with one another to reform their supply chains, a modal shift is gradually taking place. As the range of activities affected by this modal shift expands, revisions to existing industry structures and joint efforts to transport merchandise into particular regions are helping to optimize the supply chains of companies throughout Japan. As this paper has illustrated, cooperative efforts by multiple companies may be the key to accelerating the modal shift.

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# **TOWARDS A THEORY OF MACROLOGISTICS: INSTRUMENTATION AND APPLICATION**

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## **ABSTRACT**

### **Purpose**

The primary objective of this paper is to further the development of the emerging field of macrologistics by proposing a definition and a quantification construct for macrologistics. The secondary objective is to illustrate the feasibility of this approach through the application of South Africa's established macrologistics models to national-level logistics challenges.

### **Design**

The definition of macrologistics is developed through a literature survey. The instrumentation of macrologistics, i.e. the development of a quantification construct, is based on a freight demand model which provides commodity-level, spatially-disaggregated freight-flow data, followed by a related component-level logistics costs model with four endogenous logistics costs elements (transport, storage, inventory carrying costs, and management and administration costs). The important quantitative contribution is that the measurement is bottom-up and disaggregated. This instrumentation allows for a wide array of macrologistics applications which are illustrated in the results.

### **Findings and value**

The development of the emerging field of macrologistics is advanced by the development of a definition and quantification construct of macrologistics. Modelling results show that South Africa's macrologistics challenges persist because they are not receiving macrologistics management attention. The research provides a measureable approach to macrologistics costs that can benefit society on a macro level, not only as far as policy is concerned, but also to support a wide array of applications by enabling freight logistics solution development that is in line with the national freight logistics context.

### **Research implications**

This type of research is often challenged by the absence of bottom-up, spatially-disaggregated commodity-level data. The ability to develop this data cost-effectively will allow the theory of macrologistics to advance.

### **Practical implications**

The development of South Africa's freight logistics models provides an important contribution to the quantification of macrologistics costs in national economies and provides impetus for the elevation of logistics to the macroeconomic realm.

**Keywords:** Macrologistics, logistics costs, evidence-based policy, gravity modelling, South Africa

## INTRODUCTION

Efficient freight logistics is a crucial platform for creating sustainable economic growth, and the issues concerning transport economists and policymakers are by nature large-scale issues requiring a national perspective (Havenga, 2010; Müller et al., 2012). More than three decades ago, Kojima (1982) reflected on the importance of incorporating the impact of *inter alia* transport costs and input-output interactions in macroeconomic theory. Liu et al. (2006) referred to the dynamic correlation between macroeconomic development and logistics development at the scale required to both support and enable economic growth. Yet, even at a company level, strategic attention to logistics as a source of competitive advantage is a relatively new phenomenon, following on from a focus on product quality during the 1980s and customer service in the 1990s. It is therefore not surprising that the macroeconomic shift towards strategic logistics management is still in its infancy.

The backbone of all high-performing systems is management information (Fredendall and Hill, 2001). This holds true, irrespective of whether the performance of businesses, industries or entire economies is at stake. Lakshmanan and Anderson (2002) emphasise the need for performance-based research to clearly demonstrate the link between logistics infrastructure investment and economic growth, while Havenga (2010) calls for the use of macrologistics indicators to inform the development and track the performance of national logistics strategies.

Rutner and Langley (2000) found a significant relationship between efforts to quantify logistics value and the likelihood of the existence of a formal, written definition of logistics value. The authors suggest that an agreed set of definitions will aid industry professionals in delivering logistics value as it provides a common point of departure to develop value from, while consistent measurement enables benchmarking. The first step of a measurement process is to define the ultimate goal of the system being measured. This clarity provides focus and frees resources for delivery.

Following from this, the primary objective of this paper is to further the development of the emerging field of macrologistics by proposing a definition and a quantification construct for macrologistics. The secondary objective is to illustrate the feasibility of this approach through the application of South Africa's established macrologistics models to national-level logistics challenges.

The literature survey, presented in the next section, culminates in the proposal of a definition for macrologistics, addressing the primary objective. The methodology section presents a quantification construct for macrologistics through the description of South Africa's established macrologistics models. The results section interprets the outputs from the models in a macrologistics context, followed by an overview of specific macro- and meso-level applications of these models to improve the macrologistics performance. The concluding remarks summarise the outputs and proposes next steps.

## LITERATURE SURVEY

On a company level, the definition of logistics has become well established over the last four decades. Logistics is an integrative and systemic support function, applying trade-offs to determine optimal cost levels in the provision of the physical movement and storage of goods to address the time and place discrepancy between supply and demand for the purpose of conforming to customer requirements. It was, in essence, a microeconomic function that supported business growth on a firm level (Stock and Lambert, 2001; Lummus et al., 2001).

The integrative and systemic nature of the discipline is enabled by the ability to develop activity-based disaggregated cost data and to establish the impact of activities on each other, in order to enable the lowest cost of logistics for the time and place utility provided (Ferrin and Plank, 2002; Rutner and Langley, 2000). The supply chain focus is to add the trade-offs between logistics costs and the costs of purchasing, production and marketing,

to enable the lowest total cost of ownership (Ellram and Siferd, 1998). The importance of supply chain level trade-offs becomes evident as a cost increase in one activity, such as increased bulk buying, can increase logistics costs, but due to bulk discounts, the total cost of ownership is reduced (Chow et al., 1994). Similarly, this holds true for a national economy – the ability to conduct national-level trade-offs between all input costs could lead to a lower total cost for the national economy. This is well illustrated by Hardin's (1968) seminal work where he illustrated that a positive return for each single economic actor could lead to a negative collective result. Only when all stakeholders are held accountable for the full cost of their choices, will individual choices, influenced by this cost impact, aggregate for the greater good.

The definition of macrologistics proposed next is informed by these principles. It is defined within the context of macroeconomic management and concludes with a quantification construct. Macrologistics is defined as a branch of economics dealing with the performance, structure, behaviour, and decision-making of the nation's logistics to support the trade of goods to the benefit of economic actors. The objective of macroeconomic management should be to engineer the lowest total cost of ownership to the national economy through cost trade-offs between macroeconomic production factors and input costs (including economic, social and environmental costs). The contribution of macrologistics to these cost trade-offs in order to determine the lowest total cost options for the economy, is the quantification of commodity-level, spatially-disaggregated freight-flow models, and related component-level logistics costs models in support of infrastructure, policy and operational development. For the purposes of this paper, the latter is referred to as the instrumentation of macrologistics. This will inform questions such as the link between a nation's logistics facilities (e.g. ports, roads, railways and transshipment hubs), location of production facilities, spatial organisation and manufacturing practices.

However, within macroeconomics, transport costs are typically relegated to the realm of administered costs, i.e. not considering it as a distinguishing factor amongst economies and therefore not measured (Anderson and van Wincoop, 2004; Hesse and Rodrigue, 2004). The maturation of the logistics discipline has brought about attempts to rectify these matters, for instance comparing logistics efficiency factors amongst nations through the World Bank's (2016) Logistics Performance Index (LPI), national cost measurements (Rantasila and Ojala, 2015), and attempts to define the elements of macrologistics (Banomyong et al., 2008; Gleissner and Femerling, 2013). In addition, pressing global issues are increasing attention on logistics as an enabler. These include sustainability issues, humanitarian logistics, the management of food waste, the effect of reshoring on logistics configurations and the drive towards degrowth. Recent research, summarised below, highlights the attempts to improve the quantification of national logistics costs.

Weng and Du (2015) urge cost comparisons based on those portions of GDP that have direct relations with logistics activity, i.e. the transportable economy (agriculture, mining and manufacturing). They demonstrate that some of the savings that the USA has achieved over time in logistics costs as a percentage of GDP were merely due to the higher growth in the services sector compared to that of transportable GDP. Whereas China's logistics costs as a percentage of total GDP is significantly higher than that of the USA (17.8% vs. 8.5% for 2011) it is slightly less for the transportable GDP (24.5% vs. 26%). Their results also demonstrate that, while moving in a narrow band, the USA's logistics costs as a percentage of transportable GDP has been consistently higher than that of China during the time period of their analysis (1998-2011). This ratio for South Africa is more than double that of China and the USA, hovering around the 50% mark since the inception of the research (refer Figure 1).

The Australian Logistics Council (2014) ("ACL") alludes to the problems associated in the use of national accounts for understanding logistics costs, as national accounts only captures outsourced activities, i.e. not in-house logistics services. Rantasila and Ojala (2015) also highlight this problem.

Gleissner and Femerling (2013) describe macrologistics based on its components, namely the traffic system and infrastructure required to provide transport and warehousing. They expand the view to what they call "societal logistics" where the human element is included. Banomyong et al. (2008) define four components, i.e. infrastructure, institutional framework, service providers and shippers of goods. An important addition of the latter study is the addition of the institutional framework (or policy) perspective.

These studies aid the instrumentation of macrologistics by highlighting key themes: (1) the importance of the disaggregation of both GDP and logistics costs, to understand the effect of the structure of an economy on logistics costs, (2) understanding the overarching level of logistics outsourcing to address the undercounting in national statistics and (3) identifying and quantifying key macroeconomic components of logistics. Ellram and Siferd (1998) identified key barriers to strategic cost management, including complexity (relating to time, investment and onerous data requirements), culture (referring to the positioning of cost management as a strategic activity) and relevance (referring to the constant balancing act between detail and accuracy vs. usability and continuity). Integrated mathematical models are however important instruments to facilitate the holistic representation of the components of a logistics system (Islam, 2007). Following the problem statement, South Africa's macrologistics are described.

## **PROBLEM STATEMENT**

The macroeconomic contribution of logistics is not recognized, and it is therefore not developed as an integrated body of knowledge that can add macroeconomic value. In addition, a quantification construct for macrologistics is currently not embedded within the macroeconomic measurement system. This hampers the ability of the logistics discipline to support public and private sector planning, policy development and investment strategies on a macroeconomic level to achieve economic, social and environmental advantages. The primary objective of this paper is to further the development of the emerging field of macrologistics by proposing a definition and a quantification construct for macrologistics. The secondary objective is to illustrate the feasibility of this approach through the application of South Africa's established macrologistics models to national-level logistics challenges.

## **METHODOLOGY: THE INSTRUMENTATION OF MACROLOGISTICS**

### **Supply and demand per commodity on a geographical basis**

The modelling of supply (production and imports) and demand (intermediate demand, final demand, exports and inventory investments) on a geographical basis per commodity is based on the input-output table (I-O table) of the economy. Supply and demand interaction is translated into modal share through gravity modelling for 83 commodities in 372 geographical areas (356 magisterial districts, eight inland border posts, seven ocean ports and one airport), culminating in a 30-year forecast at 5-year intervals for three scenarios. In gravity modelling, a distance-decay function describes the attraction value of freight between origins and destinations over a certain distance. The decay parameter determines the slope of the distance-decay function (Wilson, 1969; de Jong and Van der Vaart, 2010).

Once freight flows have been modelled, they are aggregated into typologies to facilitate analysis and recommendations. The primary typology refers to ring-fenced logistics systems that are by nature (relevant) mode-monopolistic with known flows. The competitive surface freight transport market refers to corridor, metropolitan and rural freight flows. The methodology was developed by the authors in 1998 and applied annually since 2006 (Havenga, 2013). Results are calibrated with industry research and correlated with known freight flows. The model is a hybrid, utilising actual and modelled data. Hybrid models allow for a more comprehensive analysis of the system under analysis (Islam, 2007), as logistics performance is multi-dimensional (Chow et al., 1994).

The modelling of total supply and demand addresses a concern raised by Lyk-Jensen (2011) that freight traffic forecasting typically does not adequately incorporate international trade flows. Correlation with the national input-output table ensures that traffic volumes are not exaggerated (Liu et al., 2006).

### **Calculating logistics costs**

South Africa's logistics cost model measures logistics costs for all freight flows as received from the FDM (Havenga, 2010). Four cost components are calculated:

1. Inland transport costs: This is a mode-dependent (rail, road, pipeline) cost per tonne-km. Using actual tariff data for rail and pipelines and a highly detailed road tariff model, the cost per tonne-km is unique for each commodity travelling on each origin-destination pair. The different cost elements of road transport are determined by vehicle type; this, in turn, is determined by the commodity type, typology and route of travel. The commodity's 'preferred' vehicle type will change with changes in each of these variables. Once the vehicle type and volume are known, the cost elements can be assigned. The core drivers of transport costs, i.e. weight in tonnes and distance travelled forms the basis of the approach.
2. Inventory carrying costs: Inventory carrying costs take into account the repo rate (the central bank's interest rate) and the average time each commodity is kept in storage. This cost per tonne is unique for each commodity but is independent of origin-destination pairs.
3. Warehousing costs: Warehousing costs include all costs associated with keeping a commodity in storage. This includes rental costs, equipment costs, direct labour costs and insurance. It is calculated per tonne taking into account the average time in storage and the cost per tonne for storage for a specific commodity. The storage cost depends on the packaging type and density of the product. This cost per tonne is unique for each commodity but is independent of origin-destination pairs.
4. Management and administration costs: This cost per tonne takes into account the cost of indirect labour, administration and other indirect costs.

An externality cost extension to the logistics costs model has been developed to quantify all non-charged costs, which include emissions, accidents, congestion, policing and noise pollution (Havenga, 2015).

## **RESULTS**

### **Logistics costs**

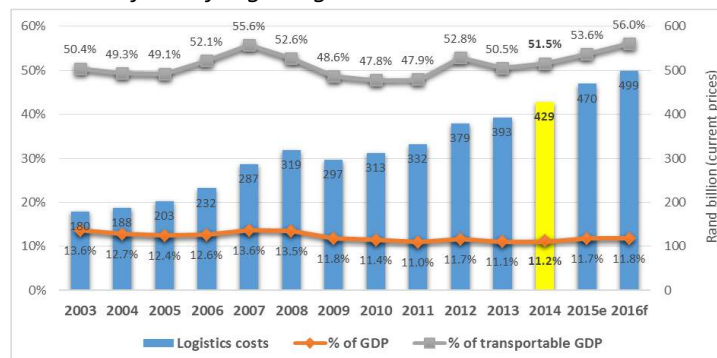
South Africa is still only one of three countries who consistently measure and publish logistics costs on a national level, the other two being the USA and Finland (Rantasila and Ojala, 2015). South Africa's logistics costs totalled R429bn (\$32bn or €29bn) in 2014 and equated to 11.2% of GDP or 51.5% of transportable GDP (refer Figure 1). Transport costs are the dominant contributor towards logistics costs, amounting to 57% of the total in 2014, followed by inventory carrying costs (15.2%), warehousing (14.6%) and management & administration costs (13%).

Demand for land freight transport reached 848 million tonnes in 2014. The primary economy (agriculture and mining) was responsible for 76% of total volume but only contributed 44% to the transportable GDP (i.e. in value terms). In contrast, the secondary (manufacturing) sector made up the remaining 24% of volume, but added 56% value to the transportable economy. Manufactured commodities are highly densified along the country's two key general freight corridors, namely Gauteng-Cape Town and Gauteng-Durban. The 848 million tonnes land freight flows in 2014 translated into 379 billion tonne-km. These volumes have increased by 119 billion tonne-km and 125 million tonnes over the past 4 years. If the dedicated ring-fenced transport systems (i.e. the rail export lines, pipelines and conveyer belts) that totalled 107.5 billion tonne-km in 2014

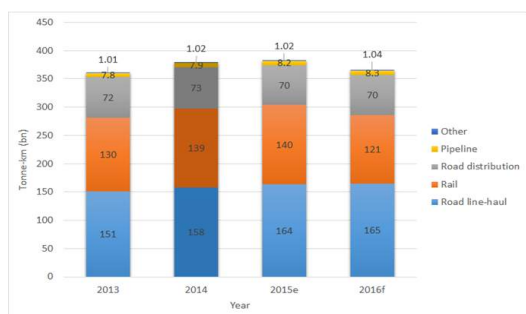


are removed, 272 billion tonne-km remain that is classified as general freight. Road freight comprises 80% of long-distance corridor freight (Figure 1).

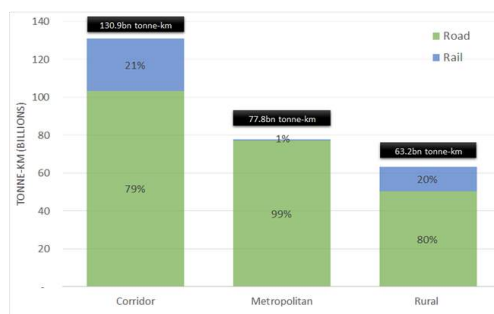
*Trends in South Africa's freight logistics costs since measurement inception*



*Tonne-km per mode (2014)*



*General freight typologies (2014)*



*Figure 1: Macrologistics instrumentation – Key outputs of South Africa's freight logistics models<sup>1</sup>*

The instrumentation of macrologistics has enabled South Africa to determine that:

- The country's logistics costs as percentage of GDP is higher than that of key trading partners (Armstrong and Associates Inc., 2016). This ratio has been stagnant during this decade, pointing to a need for a systemic shift in the logistics landscape;
- The contribution of transport costs to total logistics costs is significant; and
- The contribution of road transport to general freight transport costs, and the resulting environmental impact, is not sustainable.

These challenges persist because they are not receiving macrologistics management attention. It is hoped that the work presented in this paper can initiate the macroeconomic formalisation of logistics costs. In support of this, the instrumentation construct has already delivered important inputs to national economic challenges, both in South Africa and other developing economies. Some of these applications are summarised below.

## Application examples

The applications detailed below were enabled by the instrumentation of macrologistics. These analyses would not have been possible on a micro level, or if the instrumentation of logistics costs, i.e. the components and the cost of the flows in relation to these components, were not known.

<sup>1</sup> The calculations in the latest model are up to 2014, with an estimate for the 2015 year (2015e), and a forecast for the 2016 year (2016f) due to the considerable publication lag of macroeconomic data.

1. Disaggregated commodity flows allowed for the commodity-based identification of intermodal-friendly traffic. More than half of South Africa's potential intermodal freight moves on the country's most-dense freight corridors. Building three intermodal terminals to connect the three major industrial hubs – Gauteng, Durban and Cape Town – could enable modal shift to rail, increasing rail densities and thereby reducing transport costs (including externalities) for the identified intermodal freight flows on these two corridors by 64% (Havenga et al., 2012).
2. The disaggregated flows across borders and through seaports considered the instrumentation of operations, infrastructure and trade and the resultant costs to illustrate the advantages of coordination and the elimination of barriers. Reducing delays at South Africa's two major inland border posts can reduce the costs related to these delays by 55% due to reduced buffer stock required at the destination site, reduced costs of carrying inventory, and reduced vehicle utilisation losses due to cross border delays by (Havenga et al., 2013). Havenga et al. (2016) showed that trade documentation costs and induced transport costs due to truck and ship standing times are approximately equal to direct port charges. These costs are at least in part avoidable and can be addressed through improved port efficiencies and collaboration between the ports, industry, and the national revenue services.
3. A cost-benefit analysis based on macrologistics data for the development of freight villages and an integrated corridor design on one of the country's major corridors in a developing economy to redirect freight and decongest cities was enabled which could lead to improved national infrastructure decisions (Simpson et al., 2016). Initial indications are that logistics costs on the corridor can be halved.
4. Informing sustainability discussions through the externality cost extension to the transport cost component of the logistics cost model (Havenga, 2015). The results of South Africa's externality cost model show that transport externalities add an additional 18% to already high transport costs. The visibility of these costs is the first step towards internalisation and illustrates the desirability of a fundamental shift in the structure of the South African freight transport industry through the introduction of long-distance intermodal solutions.

## CONCLUDING REMARKS

The primary objective of this paper was to further the development of the emerging field of macrologistics by proposing a definition and a quantification construct for macrologistics. The secondary objective was to illustrate the feasibility of this approach through the application of South Africa's established macrologistics models to national-level logistics challenges.

Macrologistics is defined as a branch of economics dealing with the performance, structure, behaviour, and decision-making of the nation's logistics system (infrastructure, equipment and policies) to support the trade of goods to the benefit of economic actors. The objective of macroeconomic management should be to engineer the lowest total cost of ownership to the national economy through cost trade-offs between macroeconomic production factors and input costs (including economic, social and environmental costs). The contribution of macrologistics to these cost trade-offs in order to determine the lowest total cost options for the economy, is the quantification of commodity-level, spatially-disaggregated freight-flow models, and related component-level logistics costs models in support of infrastructure, policy and operational development. For the purposes of this paper, the latter is referred to as the instrumentation of macrologistics. The overarching modelling results provide a quantification of macroeconomic freight flows, improving the understanding of the freight flow landscape and enabling informed debate and prioritisation analysis. Modelling results show that South Africa's macrologistics challenges persist because they are not receiving macrologistics management attention. It is hoped that the work presented in this paper can initiate the macroeconomic formalisation of logistics costs. In support of this, the instrumentation

construct has already delivered important inputs to national economic challenges, both in South Africa and other developing economies.

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# EURASIAN TRADE LIBERALISATION AND TRANSPORT DEMAND IN EURASIAN REGION

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## ABSTRACT

### **Purpose of this paper**

Economic integration in Eurasian region is being pursued with the creation of a Eurasian Economic Union (EAEU). Asian countries such as China and Korea seek economic cooperation with EAEU member countries to accelerate regional and bilateral trade. Physical barriers in this region is transport infrastructure connecting EAEU countries and East Asian countries. International organisations are organising collaborative development projects to improve transport linkage between Europe and Asian countries such as Euro-Asian Transport Linkages (EATL). However transport demand which is an essence of infrastructure development projects has not been investigated. This paper estimates transport demand in the linkages between EAEU countries and Asian countries using dynamic computable general equilibrium model.

### **Design/methodology/approach**

This paper employs a global computable general equilibrium model which is referred as Global Trade Analysis Project. Under scenarios of trade liberalisation between EAEU and Asian countries, bilateral trade volumes are estimated and the estimated volumes are converted into freight transport demand to quantify the impacts of the Eurasian trade liberalisation on transport freight demand.

### **Findings**

It is found that trade liberalisation reducing tariff have varying impacts on different cargo types and transport modes. It is shown that tanker and bulk transportation is demanded more than container transportation is needed.

### **Value**

There has been methodological challenge to estimate transport demand in inter-countries linkage. Combining CGE model and conversion factors provides opportunity to investigate the impact of trade liberalisation in a wide region on freight transport demand.

## INTRODUCTION

Economic integration in Eurasian region is being pursued with the creation of a Eurasian Economic Union (EAEU) (Tarr, 2016). Even if Asian countries such as China and Korea seek economic cooperation with EAEU member countries to accelerate regional and bilateral trade, the region has encountered some transport connectivity issues. To overcome the issues, international organisations, in particular UNECE, are organising collaborative development projects to improve transport linkage between Europe and Asian countries such as Euro-Asian Transport Linkages (EATL) (UNECE, 2012).

Many studies have been conducted to analyse the effects of the trade liberalisation (Brown et al., 2003; Herterl et al., 2004; Kitwiwattanachai et al., 2010; Topalova, 2010; Francois et al., 2013), but the previous studies mainly focused on economic impacts of trade

liberalisation. A few studies analysed the changes in trade volumes in particular maritime transportation of trade liberalisation. Lee, Wu, and Lee(2011) estimated seaborne cargo trade volumes caused by free trade agreement(FTA) between China and Taiwan called the Economic Cooperation Framework Agreement(ECFA). Lee and Lee(2012) analysed the changes in trade volumes of FTA among South Asia, South America, and Africa, namely IBSA. Lee, Lee, and Yang(2013) quantified the impacts of Korea-ASEAN FTA on changes in seaborne cargo volumes. The studies commonly used global CGE models to simulate various scenarios of trade liberalisations. To the best of our knowledge, we have not found any study associated with estimating transport demands of the trade liberalisation between Eurasian countries.

This paper aims to estimate transport demand in the linkages between EAEU countries and Asian countries using dynamic computable general equilibrium (CGE) model. By employing global computable general equilibrium model which is referred as Global Trade Analysis Project, bilateral trade volumes are estimated under scenarios of trade liberalisation between EAEU and Asian countries. In addition, the estimated trade values are converted into freight transport demand such as trade volumes to quantify the impacts of the Eurasian trade liberalisation on transport freight demand.

## **ANALYSIS MODEL AND SCENARIO**

### **GTAP Model and data**

The CGE model used in this study considers the international trade such as import, export and customs as well as the domestic economy: production, consumption, investment, and government expenditure in each industry. The CGE model can estimate the ripple effects caused by changes in the international economic environment. Furthermore, the CEG model can be widely used to capture the impacts of bilateral or multilateral trade liberalisation such as free trade agreement. The most commonly used model to capture the effects of economic integration or trade liberalization among the CGE models is the standard GTAP model developed by Hertel(1997). However, the standard GTAP model has static in nature which may fail to capture changes in long-term period. To overcome this limitation, we rely on recursive dynamic GTAP model. The recursive dynamic GTAP model is developed by Ianchovichina(1998), and the model can estimate the economic effects under dynamic framework.

For investment and capital stock,

$$VK(r) \cdot qk(r) = 100NETINV(r) \cdot time$$

Where  $VK(r)$  presents the value of the capital stock in region  $r$ ,  $qk(r)$  represents percentage changes in the capital stock in region  $r$ ,  $NETINV(r)$  is the value of net investment in region  $r$ , and  $time$  is variable measuring the length of the simulation period.

For total wealth and savings,

$$WQHHLDR(r) \cdot wqh(r) = WQHFRM(r) \cdot pcgds(r) + WQHTRUST(r) \cdot pqtrust + 100 \cdot SAVE(r) \cdot time$$

Where  $WQHHLDR(r)$  presents total wealth of regional household in region  $r$ ,  $wqh(r)$  represents percentage changes in total wealth in equity owned by the household in region  $r$ ,  $WQHFRM(r)$  denotes wealth in equity owned by household in region  $r$ ,  $pcgds(r)$  represents percentage change in the price of investment goods in region,  $r$ ,  $WQHTRUST(r)$  denotes total wealth in equity owned by household in  $r$ ,  $pqtrust$  is percentage change in the price of equity invested in the trust,  $SAVE(r)$  represents savings in region  $r$ , and  $time$  is variable measuring the length of the simulation period (Ianchovichina and McDougall, 2000).

As a dataset for using the recursive dynamic GTAP model, GTAP version 8.1 database with base year of 2007 is used. The database consists of 134 countries/regions, 57 industry sections, 5 primary factors: land, capital, nature resources, and skilled- and unskilled-labour.

For the CGE analysis, the countries should be firstly classified, and this study categorized 9 groups: Korea, China, Japan, U.S.A, and EU including 28 countries, Mongolia, Russia, former Soviet Union countries: Kazakhstan, Belarus, Kyrgyzstan, and rest of Soviet Union countries, and other countries to see the impacts of international trades of FTAs between Korea and Eurasian countries.

The industry sections are grouped into 13 categories: rice, agriculture, fisheries, gas, minerals and petroleum, textiles, other manufactures, chemical products including rubber and plastic, metal products including ferrous metals, other metal products, automobiles, transport equipment, electricity and electronics, and machinery. Of the industrial sections, we specify natural resources into two groups: gas and minerals and petroleum because the natural resources are the main product of Eurasian countries.

In this study, the primary factors of production are classified as land including natural resources, labour, and capital in order to set up stable baseline scenario. In addition, all the primary factors of production cannot be transferred between countries in the standard GTAP model. However, it is assumed that capital can be transferred between countries in this study.

### Scenarios

To analyse the changes in trade volume by liberalisation of FTAs between Korea and Eurasian countries, four scenarios including baseline with three time periods: Phase 1(2016 to 2020), Phase 2(2021 to 2025), and Phase 3(2026 to 2030) are considered (see Table 1).

Table 1: Scenarios

	Phase 1 (2016 to 2020)	Phase 2 (2021 to 2025)	Phase 3 (2026 to 2030)
	Changes in macroeconomics indicators (GDP, population, and labour)		
Baseline	Effects on Korea-US FTA, Korea-China FTA, Korea-EU FTA, and EAEU		
Scenario 1	Korea-Eurasia FTA(Korea, Mongolia, Russia, China, and former Soviet Union countries), 50% of tariff elimination rate		
Scenario 2	Korea-Eurasia FTA(Korea, Mongolia, Russia, China, and former Soviet Union countries), 75% of tariff elimination rate		
Scenario 3	Korea-Eurasia FTA(Korea, Mongolia, Russia, China, and former Soviet Union countries), 100% of tariff elimination rate		

Baseline considers changes in macroeconomic indicators such as GDP, population, and labour. FTAs between Korea and USA, China, and EU are included in the baseline. In addition, the baseline considers FTAs between Russia and former Soviet Union (e.g., EAEU).

The baseline assume that all FTAs with Korea except Korea-China FTA apply no tariff for all goods other than rice. Korea-US FTA and Korea- EU FTA set tariff elimination rates at 100% because the tariff elimination rate is close to 100% for items except rice. In the case of Korea-China FTA, Korea is assumed to have 40% and 80% of tariff elimination rates on Chinese agricultural products and Chinese industrial products, respectively. The tariff elimination rate is assumed to be 56% for Korean agricultural products and 66% for Korean industrial products, respectively.

Three alternative scenarios commonly consider liberalisation of FTAs between Korea and Eurasian countries including Mongolia, Russia, China, and former Soviet Union countries. Three different tariff elimination rates between Korea and Eurasian countries are assumed: 50% for Scenario 1, 75% for Scenario 2, and 100% for Scenario 3, respectively. It is assumed that rice is excluded from the concession for all alternative scenarios.

## ANALYSIS RESULTS

### GDP and trade value

The analysis results of changes in GDP after FTAs between Korean and Eurasia countries are summarized in Table 2.

Table 2: Percentage changes in GDP after FTA compared to the baseline

Scenario	Period	Korea	Mongolia	Russia	Former Soviet Union
Scenario 1 (50% of tariff elimination rate)	Phase 1 (2016 to 2020)	0.023	0.063	0.04	0.01
	Phase 2 (2021 to 2025)	0.044	0.116	0.08	0.02
	Phase 3 (2026 to 2030)	0.056	0.124	0.07	0.02
	Phase 1 (2016 to 2020)	0.037	0.089	0.06	0.02
Scenario 2 (75% of tariff elimination rate)	Phase 2 (2021 to 2025)	0.070	0.171	0.12	0.03
	Phase 3 (2026 to 2030)	0.090	0.184	0.11	0.03
	Phase 1 (2016 to 2020)	0.051	0.109	0.08	0.02
	Phase 2 (2021 to 2025)	0.099	0.223	0.16	0.03
Scenario 3 (100% of tariff elimination rate)	Phase 3 (2026 to 2030)	0.129	0.241	0.15	0.04

After FTAs between Korea and Eurasian countries, it is expected that the GDP growth rate of Mongolia is the highest, and former Soviet Union is the lowest for all scenarios. After the FTAs, Korea's GDP growth rate is the third. If Korea cuts tariffs by 50% with Eurasian countries, Korea's real GDP will increase by about 0.056% in the long term, Mongolia with about 0.124%, Russia with about 0.07%. Countries showed an increase of about 0.02%. Changes in GDP of each country after FTAs have similar patterns by scenario. In other words, the higher the tariff elimination rate, the greater the growth rate of real GDP, but increasing rates of GDP vary on each country. In the long run, Korea's real GDP will range from 0.056% to 0.129%.



Table 3: Changes in trade by industrial sector after FTAs with Eurasian countries compared to the baseline (Scenario 1)

Industrial sector (units: Million USD)			Mongolia			Russia			Former Soviet Union			China		
			2015~ 2020	2021~ 2025	2026~ 2030	2015~ 2020	2021~ 2025	2026~ 2030	2015~ 2020	2021~ 2025	2026~ 2030	2015~ 2020	2021~ 2025	2026~ 2030
1	rice	I	-	-	-	-	-	-	-	-	-	189	188	189
		E	-	-	-	-	-	-	-	-	-	-	-	-
2	agriculture	I	0.93	0.92	0.93	344	345	343	21.7	21.7	21.6	2,704	2,699	2,693
		E	46.1	45.9	46.1	319	317	319	137	136	137	863	863	865
3	fisheries	I	-	-	-	815	820	830	1.41	1.41	1.40	1,013	1,013	1,011
		E	0.12	0.12	0.12	8.83	8.82	8.73	0.05	0.05	0.05	224	224	223
4	gas	I	-	-	-	12,382	12,382	12,382	706	724	741	906	906	906
		E	-	-	-	-	-	-	-	-	-	-	-	-
5	minerals and petroleum	I	17.3	17.3	17.3	2,015	2,028	2,040	-	-	-	746	744	743
		E	0.12	0.12	0.13	16.2	16.1	16.0	1.09	1.09	1.09	167	167	168
6	textiles	I	2.34	2.35	2.36	3.90	3.91	3.83	7.85	7.91	7.92	7,583	7,573	7,570
		E	11.7	11.7	11.8	242	244	245	368	370	372	2,604	2,610	2,616
7	other manufactures	I	0.28	0.28	0.28	266	266	262	12.9	12.9	12.9	8,114	8,092	8,087
		E	33.6	33.5	34.0	412	411	417	268	268	271	2,094	2,100	2,107
8	chemical products	I	0.01	0.01	0.01	367	368	366	232	233	235	9,479	9,457	9,451
		E	59.6	59.9	60.3	1,448	1,445	1,442	642	639	641	28,985	29,033	29,078
9	metal products	I	1.69	1.70	1.70	1,564	1,567	1,549	248	251	251	14,660	14,640	14,672
		E	37.3	37.5	37.5	781	779	784	462	464	469	8,109	8,130	8,154
10	automobiles	I	0.04	0.04	0.04	1.52	1.51	1.50	0.74	0.74	0.74	1,199	1,195	1,193
		E	55.4	55.6	55.8	5,051	5,016	5,047	2,132	2,137	2,153	8,032	8,056	8,073
11	transport equipment	I	0.02	0.02	0.02	37.4	37.5	36.8	-	-	-	803	799	797
		E	1.76	1.77	1.77	1,749	1,746	1,780	71	72	72	540	544	544
12	electricity and electronics	I	2.15	2.15	4.30	28.9	29.0	28.5	9.24	9.31	9.32	33,180	33,126	33,130
		E	26.8	26.9	27.0	1,322	1,316	1,328	474	478	481	54,493	54,568	54,690
13	machinery	I	0.37	0.37	0.37	27.6	27.7	27.1	7.16	7.20	7.23	9,898	9,868	9,862
		E	84.0	84.6	85.2	1,860	1,839	1,864	933	936	945	30,580	30,709	30,803

\*"I" and "E" stand for import and export, respectively

Mongolia will be about 0.124% to 0.249%. Russia will change by 0.02% to 0.04%. GDP of former Soviet countries will increase about 0.01%

The changes in overall trade by scenario after FTAs between Korean and Eurasian countries are presented in Table 4. Korea's exports to and imports after FTAs with Eurasian countries are expected to be increased for all scenarios. Trade values between the two regions are greater as the tariff elimination rate is higher. As expected, Korea has the largest share of trade with China among Eurasian countries. China accounts for 85% and 82% of Korea's exports to and imports from Eurasian countries, respectively

Table 4: Overall changes in trade value after FTAs with Eurasian countries

(Units: Million USD)		Scenario 1			Scenario 2			Scenario 3		
		2015~ 2020	2021~ 2025	2026~ 2030	2015~ 2020	2021~ 2025	2026~ 2030	2015~ 2020	2021~ 2025	2026~ 2030
Export to	Mongolia	0.356	0.358	0.360	0.385	0.387	0.389	0.416	0.419	0.422
	Russia	13.2	13.1	13.2	15.3	15.2	15.4	17.3	17.7	17.9
	Former Soviet Union	5.5	5.5	5.5	6.4	6.4	6.5	7.5	7.5	7.6
	China	136.7	137.0	137.3	136.3	136.6	137.0	135.8	136.2	136.6
	Total	155.7	156.0	156.5	158.3	158.7	159.2	161.0	161.9	162.5
Import from	Mongolia	0.025	0.025	0.027	0.027	0.026	0.028	0.028	0.027	0.029
	Russia	17.9	17.9	17.9	18.1	18.2	18.2	18.4	18.5	18.5
	Former Soviet Union	1.2	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
	China	90.5	90.3	90.3	90.5	90.4	90.3	90.6	90.4	90.4
	Total	109.6	109.5	109.5	110.0	109.8	109.7	110.3	110.2	110.2

In Scenario 1, Korea mainly imports natural resources such as gas, minerals and oil from Eurasian countries. Korea has the largest amount of imports from Mongolia to minerals and petroleum, while the electricity and electronics industries imported from Mongolia more than doubled from Phase 2 to Phase 3. Korea's imports from Russia are the highest in minerals and petroleum, followed by imports of metal products. From former Soviet federal, Korea mainly imports gas, metal, and chemical products. Electricity and electronics, metal products, machinery, and chemical products are dominant imports from China. On the other hand, Korea's exports for all industries other than rice and fisheries to Mongolia and Russia are expected to be increased over 10% and over 20% in the long term, respectively. Korea's exports to former Soviet Union countries increase by more than 20% for all industrial sectors other than rice, fisheries, and electricity. In particular, export rate of textiles to former Soviet Union countries is very high.

### Trade volume by cargo type

Once estimating the trade values by FTA with Korea and Eurasian countries, estimating trade volumes by cargo type are keen of interests because South Korea is handling 99% of import and export cargo through shipping. Trade volumes by cargo type are estimated by converting from trade values to volumes. In this paper, we assume that all cargos are carried by five types: container, LNG, chemical tank, bulk, and car, and each industrial sector has only one cargo type.

Table 5: Changes in Korea trade after FTA compared to the baseline

Industry sector	Converting rate (kg/dollar)	Cargo type
fisheries	0.35	Container
gas	6.33	LNG
textiles	0.38	Container
other manufactures	0.19	Container
chemical products	0.9	Chemical Tank
metal products	2.43	Bulk
automobiles	0.19	Car
transport equipment	0.11	Container
electricity and electronics	0.08	Container
machinery	0.23	Container

\*converting rates for rice, agriculture, and petroleum cannot be obtained

In Scenario 1, bulk and container are the major cargo types imported from Mongolia because Korea mainly imports steel and metal and textile, and other manufacturing goods from Mongolia. In the case of imports from Russia and former Soviet Union countries, LNG is the largest cargo because of importing natural resources such as gas, steel, and metal. Bulk is dominant import cargo type with China followed by Container, chemical tank, LNG, and car. On the other hand, Korea's exports to Eurasian countries are transported by all types of cargoes except LNG. In particular, chemical tank, bulk, and container account for 41%, 34%, and 21%, respectively. It means that tanker and bulk transportation is demanded more than container transportation is needed after FTAs between Korean and Eurasian countries.

## DISCUSSION AND CONCLUSION

This paper relies on dynamic CGE model to simulate various scenarios and to quantify the changes in seaborne trade volume of trade liberalisation between Eurasia countries and East Asia, in particular Korea. Estimating the impacts the trade liberalisation on seaborne cargo volume is important because most international trades of Korea are carried by maritime transportation.

This study attempts to evaluate four scenarios including the baseline and three alternative scenarios considering tariff elimination rates after trade liberalisation between Eurasia countries and East Asia. In addition, these scenarios consists of three time phases from 2016 to 2030. Based on the results, as the tariff elimination rate increases, the growth rate of real GDP is greater, but increasing rates of GDP vary on each country. In addition, it turns out that FTA between Eurasia countries and Korea will increase the demands of tanker and bulk more than container.

This study mainly focuses on estimating shipping demands of trade liberalisation between Eurasia countries and Korea. However, trade volumes are actively carried by other transportation modes such as air transportation, rail, and trucking. This part should be covered by the future research.

Table 6: Changes in trade volumes by cargo type after FTAs with Eurasian countries compared to the baseline (Scenario 1)

(units : 100 tons)		Mongolia			Russia			Former Soviet Union			China		
Cargo type		2015~ 2020	2021~ 2025	2026~ 2030	2015~ 2020	2021~ 2025	2026~ 2030	2015~ 2020	2021~ 2025	2026~ 2030	2015~ 2020	2021~ 2025	2026~ 2030
Container	import	12	12	14	3,500	3,519	3,543	83	84	84	97,973	97,775	97,734
	export	325	327	330	8,992	8,941	9,062	4,511	4,530	4,568	129,179	129,574	129,922
LNG	import	-	-	-	783,767	783,767	783,767	44,712	45,857	46,908	57,350	57,350	57,350
	export	-	-	-	-	-	-	-	-	-	-	-	-
Chemical tank	import	-	-	-	3,306	3,309	3,291	2,088	2,098	2,112	85,308	85,111	85,063
	export	536	539	542	13,028	13,007	12,980	5,777	5,754	5,770	260,866	261,293	261,706
Bulk	import	41	41	41	38,008	38,088	37,641	6,032	6,090	6,104	356,234	355,751	356,522
	export	905	911	912	18,988	18,927	19,039	11,223	11,279	11,398	197,054	197,556	198,138
Car	import	-	-	-	3	3	3	1	1	1	2,279	2,270	2,267
	export	105	106	106	9,597	9,531	9,589	4,051	4,060	4,090	15,260	15,306	15,339

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# **M&A AND THE CHANGE OF THE LOGISTICS SERVICE INDUSTRY – AN ANALYSIS OF INVOLVED FIRMS AND THEIR RIVALS**

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## **ABSTRACT**

### **Purpose**

The last decade has become an active period for mergers and acquisitions (M&A) in the logistic service industry. However, studies on the effect of these transactions on the involved companies' shareholder wealth are scarce. In addition, a merger of two player may affect the whole market due to changes in the business strategies or the market power of companies. The purpose of our analysis is to find out whether there are effects overall market or just on the parties of a transaction.

### **Design**

We conduct an empirical study using the event study methodology with a sample of 628 worldwide M&A deals and identify for each transaction a rival portfolio. We analyse whether these rivals gain or lose shareholder's wealth because of the M&A. We divide the rivals in the closest and the three closest rivals for each company, identifying whether the effects are more pronounced for the closest rival.

### **Findings**

We find that acquirers' shareholder in the logistics service sector in contrast to other industries (e.g. banks, insurance) experience significant gains from a M&A announcements. In line with other industries, targets show positive abnormal returns of about 25%. We find that the acquirer's rivals do not show any abnormal performance, whereas the results indicate a positive gain for rivals of the targets.

### **Value**

For the first time we investigate for shareholder wealth effects for all possibly affected parties of an M&A transaction, the acquirer, the target and their rivals in the logistics service industry.

## INTRODUCTION

In the last decades, the demand for logistic services has increased considerably due to the ongoing transformation of manufacturing involving its global dispersion and fragmentation (Brennan et al., 2015). As a result, the logistics industry has undergone significant changes in accordance to the market developments towards more cohesive and global logistics services. Simultaneously, freight rates, especially in shipping, are declining continuously since almost a decade wherefore logistics service providers (LSPs) find themselves in a situation in which costumers are expecting high-standard services at low cost (Meidutė-Kavaliauskienė et al., 2014). Beside internal changes and organic growth to cope with the outlined challenges, mergers and acquisitions (M&A) are important vehicles influencing firms' business, product and geographic strategy (Ferreira et al., 2014). Indeed, 2015 has even become one of the most active years for M&A in logistics service industry with a total deal value of approximately \$178 billion (PWC, 2015). The majority of acquisitions made were of horizontal nature and served expansion purposes in terms of geography and market positioning (cf. PWC, 2010 and see, for example, BBA Aviation PLC's acquisition of Landmark Aviation or XPO Logistics Inc.'s acquisition of Norbert Dentressangle SA). However, M&A in the logistics service industry increasingly serve the need to expand intermodal capabilities or services provided (Carbone and Stone, 2005) as e.g. XPO's \$335 million acquisition of Pacer in early 2014 (PWC, 2015) or UPS's \$1.8 billion acquisition of Coyote Logistics, a high-tech and asset-light start-up (KPMG, 2016). Aimed at covering entire logistic chains by positioning as integrated logistic provider, offering customized capabilities across the spectrum of logistics services and serving customers all over the globe, M&A have become an increasingly attractive option for logistic service providers to pursue growth and represents an integral part of their corporate strategy (Carbone and Stone, 2005).

The impact of M&A in the logistics service industry in terms of stock market reaction after the announcement however, has, with the exception of Darkow et al. (2008) and Andreou et al. (2012) not been considered so far. Darkow et al. (2008) and Andreou et al. (2012) only consider the immediate effects for the acquirer and target companies and do not investigate the impact for other companies that could also be influenced by this decision. Major corporate events, and M&As in particular, have the potential to alter the competitive structure of an entire industry and are therefore likely to effect the rivals of the merging institutions as well. Consequently, the paper at hand takes up this issue by analysing M&A announcements taken place between 1996 and 2015 and their effect on the shareholder wealth of rival companies. The aims of the article are twofold. First, we analyse whether acquirer and target companies undertaking M&A transaction create shareholder wealth as positioning as integrated logistic provider still offer growth opportunities. Second, if market power considerations or economies of scale play a role in the motives of M&A decisions for logistic providers, we should observe spill over effects for the rivals of acquirer and target.

The remainder of this paper is organized as follows. Section 2 provides a structured overview on post-merger performance implications as well as on different research hypothesis for related rivals and industry effects. Section 3 outlines the methodology including the data search and selection process, the resulting sample, and the empirical models. The findings of the short-term event study approach are presented in Section 4. Finally, Section 5 concludes the paper by summarizing the results and discussing its implication for the logistics service industry.

## LITERATURE REVIEW

Aimed at covering the entire logistic chain by positioning as integrated service provider, offering customized capabilities across the spectrum of logistics services and serving customers all over the globe, mergers and acquisitions have become an increasingly attractive option for logistic service providers to pursue growth and diversification (Carbone and Stone, 2005). Besides its ever increasing practical importance, only few industry-specific M&A studies aimed at shedding light on the implications for the logistics industry or the companies involved. In addition, the empirical results of previous studies on the

post-merger performance of acquiring and target firms remain ambiguous (cf. Seth et al., 2002). Early cross-industry studies, typically examining the performance effect of transactions on the acquiring firm, suggested that acquisitions did not enhance firm value either in the short-term (Eckbo, 1983) or in the long-term (Agrawal et al., 1992). In some studies, acquisitions were even found to corrupt acquiring firm value (Seth et al., 2002). Besides early research predominantly addressing the performance effect for acquiring firms, the returns accrued by target firms have also been subject of analysis. Those studies show that targets often experienced significant positive returns (Asquith & Kim, 1982; Datta et al., 1992). These results have also been supported by combined acquirer and target analysis revealing significantly positive joint outcomes which, however, mostly originate from target gains while acquiring firms realize neutral or negative returns (Carow et al., 2004). A comprehensive summary of post-merger performance effects in cross-industry M&A studies can be found in Bruner (2002). In contrast to the findings of general cross-industry studies, recent studies from the logistics service industry reveal positive abnormal returns for the shareholders of both companies involved and the combined entity (Darkow et al., 2008; Andreou et al., 2012). However, the positive average synergistic deal value accrues mostly to targets' shareholders rather than to acquirers' shareholders (Andreou et al. 2012).

In the light of the significant performance effects for the companies involved, some studies take an even broader perspective and analysis the industry impact of M&As represented by the performance effect on respective rivals. Beginning with Eckbo (1983), several studies revealed that rivals of acquisition targets earn significant, positive abnormal returns. This has frequently been explained by the **Collusion Hypothesis** in according to which horizontal transactions reduce competition and facilitate collusion (cf. Fee and Thomas, 1999). Since horizontal mergers and acquisitions reduce the monitoring cost by decreasing the number of competitors, the probability of detecting cheating members within a cartel increases and by thus, collusion becomes more likely and stable in the short run (cf. Stigler, 1964). However, Eckbo (1983), Stillman (1983), and Eckbo and Wier (1985) all reject the collusion hypothesis, leaving the explanation for positive returns to rivals unclear. Similarly, rivals of acquisition targets are assumed to earn abnormal positive returns due to the increased probability that they can be targets themselves. According to the **Acquisition Probability Hypothesis**, positive abnormal returns are independent of the form and outcome of preceding transactions, increase with the degree of surprise about the acquisition and are significantly higher for rivals that subsequently become targets (cf. Song & Walking, 2000).

Other studies, however, have also shown negative abnormal returns for the rival companies (Shahrur 2005; Mitchell & Mulherin, 1996). This can be explained by the fact that transactions frequently aim for synergistic gains by realizing operational and financial efficiencies. In addition, the M&As are "massage bearers" of the fundamental changes. According to the **Economies of Scale and Scope Hypothesis**, this leads to increasing factor prices while lowering the sales prices which deteriorates the competitive position of rival companies unless they can adopt the same cost-efficient production process. Hence, the net impact on the rivals will be a reduction in their market value (Chatterjee, 1986). Similarly, it has been shown that rival companies earn abnormal negative returns if mergers confer strong negative externalities on the firms outside the merger. Following the **Pre-emptive Hypothesis**, companies also engage in M&A activities to pre-empt their partner if becoming an insider is better than becoming an outsider. For the rival companies, this is to be found a forgone opportunity for leveraging potential synergies that may now be to the advantage of a competitor (Fridolfsson & Stennek, 2005).

The preliminary discussion suggests that rivals of acquisition targets should earn significant, positive abnormal returns given that transactions take place in industries with a low degree of sectoral concentration and aim for geographical or service-related diversification rather than realizing operational efficiencies. However, given the high dependency of post-merger performance on the corresponding industry (Campa and



Hernando, 2004), the present study aims at investigating the effect of mergers and acquisitions on the respective rival companies in the logistics service industry.

## DATA AND METHODOLOGY

### Sample generation

To identify potential industry effects, the performance of corresponding rival samples is compared against an appropriately chosen benchmark. The process for identifying the rival samples is similar to sampling procedures used in the literature (see, for example, Hendricks and Singhal, 2005). Our approach can therefore be summarised as follows:

**Step 1:** The sample of M&A transactions is obtained from the Securities Data Corporation (SDC) Platinum / Thomson Reuters database and takes into account all events announced between January 1st, 1996, and December 31st, 2015. At the time of the transaction the primary business activity of both, the acquirer and the target had to be in the logistic service industry.<sup>1</sup> In addition, the acquirer had to purchase a majority stake of at least 50% of the outstanding shares or of the private equity, for publicly-traded and privately-held targets, respectively and the transaction had to be completed by now. Events that were distorted by other mergers and acquisitions during the event window were eliminated to control for confounding events. We also eliminated all events that could be affected by announcements about alliance founding (e.g. New World Alliance), open skies agreements (e.g. EU-US Open Skies Agreement), free trading agreements (e.g. NAFTA) or granting cabotage rights (e.g. unrestricted cabotage permit for all EU members). Finally, all non-exchange listed acquirer companies are excluded from the sample and events with insufficient stock data and/or weak trading pattern in the estimation and event period were removed (note that stock returns with sufficient trading volumes were a prerequisite for analysing the impact of M&A deals on the shareholders' wealth). These criteria lead to an event sample of 826 deals. The Data is obtained from the Securities Data Corporation (SDC) Platinum /Thomson Reuters database.

**Step 2:** We collect all worldwide listed logistic service companies from the Thomson ONE Database by using the identified SIC Codes (again we focus on the primary code) and organize them to regions based on the company's country of origin.<sup>2</sup> This leads to a sample of 1,995 listed logistic service companies.

**Step 3:** We search for potential rival candidates for each transaction and do this for both sides, for the acquirer and also, if listed, for the target company. Therefore, we define that a rival candidate has to be located in the same region as the acquirer/target and has an identical primary SIC Code as the acquirer/target. Rival candidates with illiquid trading patterns are dropped in the selection process.

**Step 4:** Companies with a market value more than 50% below or 100% above the market value of the bidder/target firm are excluded from the list of potential rivals. Therefore, we compare the market values from the end of the year prior the announcement year. The relevant data is obtained from Thomson Reuters Financial Datastream.

**Step 5:** In the last step, we rank the found rival candidates by market value, return on equity and total assets. Therefore, we use the arithmetic mean of the three rankings. For the acquirer side this leads us to a final sample with 629 observations where we have at least 1 rival and 477 observations where we have 3 rivals identified. For the target side we get a final sample with 32 observations where we have at least one rival and 29 observations where we have at least 3 rivals identified.

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<sup>1</sup> Logistics service providers are identified by the four-digit Standard Industrial Classification (SIC) codes 4011, 4013, 4212, 4213, 4214, 4215, 4222, 4225, 4226, 4231, 4412, 4424, 4449, 4491, 4492, 4493, 4499, 4512, 4513, 4522, 4581, 4731, 4741, 4783, 4785.

<sup>2</sup> The following regional categories have been considered: Northern America, Latin America, Eastern Europe, Western Europe, Southern Asia, Eastern Asia, Western Asia, Australia, Northern Africa, and Southern Africa.

### Event study methodology

In order to determine whether M&A have a significant impact on acquirers' shareholder wealth, we employ an event study analysis introduced by Dodd and Warner (1983) and Brown and Warner (1985) that is a common method in financial research (cf. Corrado, 2011). Literature endorses the use of a firm's stock price (for publicly traded firms) as an appropriate representation of its market value. The methodology provides the linkages between managerial decisions, actions and the resulting value created for the firm.

The normal stock return is estimated using a 252 trading day period (one whole trading year) from 262 days prior to the event day ( $t=-262$ ) to 11 days prior to the event day ( $t=-11$ ) with:

$$R_{i,t} = \hat{\alpha}_i + \hat{\beta}_i R_{m,t} + \varepsilon_{i,t} \quad (1)$$

where  $R_{i,t}$  is the return of stock  $i$  on day  $t$  during the estimation period,  $R_{m,t}$  is the return of the benchmark index,  $\hat{\alpha}_i$  and  $\hat{\beta}_i$  are the regression coefficients of stock  $i$ . Datastream's value-weighted total return national stock market index of LSP  $i$ 's country of origin is used as the benchmark index.

The cumulative abnormal return (CAR) for stock  $i$  during the event window  $[\tau_1, \tau_2] \in [-5; 5]$  is calculated by adding daily abnormal spread changes 5 days prior to the event up to 5 days subsequent to the event. To test whether the ACARs are statistically different from zero, we use the parametric test statistic developed by Kolari and Pynnönen (2010), the KP-test. In addition, we apply the nonparametric test statistics introduced by Corrado (1989), which was later refined by Corrado and Zivney (1992), the CZ-test.

### RESULTS

The results for the acquirer and its rival are provided in Table 1. Upon the immediate announcement of a deal, acquirers earn a significant 1.25% abnormal return in the  $[-1, 1]$  event-window around the announcement date. In the 11 days around the announcement day, the value gain remains comparatively stable at about 0.76%. Mainly all event windows are highly significant at the 1%-level. This finding is in line with prior research in this industry (cf. Darkow et al., 2008) but, moreover, reveals the exceptional role of M&A in the logistics service industry. Unlike results from the majority of other industries, positive short-term returns to acquirers represent the capital market's perception of extraordinary synergy potentials and future benefits of the transaction. Panel B and Panel C show the results of the related rivals. In contrast to the reactions of the acquirers' stock price, we do not find any statistically significant abnormal return for the rival portfolio. The results are largely the same for the closest three rivals and the closest rival. These results show that acquirers benefit from M&A deals, but there are neither positive nor negative spill over effect for other market participants. The increase in market power or the economies of scale by M&A seems not to change the overall market conditions in the logistics service industry.

**Table 1: Results for acquirer and its rivals.**

Event window	ACAR	Median CAR	CAR >0	BMP (Z-score)	KP (Z-score)	CZ (Z-Score)	Sample size
<i>Panel A: Acquirer</i>							
[-5;5]	0.76%	0.19%	51.36%	2.493**	2.697***	0.79	477
[-2;2]	1.17%	0.62%	54.93%	4.449***	4.416***	2.918***	477
[-1;1]	1.25%	0.69%	57.23%	5.224***	5.169***	4.137***	477
[0;0]	0.62%	0.03%	50.52%	3.623***	3.709***	2.158**	477
<i>Panel B: Acquirers' closest rival</i>							
[-5;5]	0.46%	-0.23%	48.01%	0.68	0.294	-0.903	477
[-2;2]	0.44%	-0.40%	46.12%	1.447	1.207	0.074	477
[-1;1]	0.35%	-0.03%	49.48%	1.672*	1.651*	0.283	477
[0;0]	0.08%	-0.26%	44.23%	0.434	0.354	-1.756*	477
<i>Panel C: Acquirers' average rival</i>							
[-5;5]	-0.17%	-0.26%	47.80%	-1.099	-1.161	-1.091	1431
[-2;2]	-0.04%	-0.20%	47.59%	-0.315	-0.252	0.275	1431
[-1;1]	-0.05%	-0.12%	47.80%	-0.142	0.058	0.131	1431
[0;0]	-0.06%	-0.19%	44.93%	-0.773	-0.556	-1.238	1431

\*\*\*, \*\*, \* denotes statistical significance at the 1%, 5%, and 10% level, respectively

In a next step, we analyse the influence of M&A on the target side. Table 2 shows the results for the target companies and their respective peers. Panel A provides the results for the public-listed target companies. Most of the targets are held privately and therefore excluded in our study. The results for the target sample clearly show large, positive and highly significant abnormal returns during the days surrounding the transaction date. In the eleven days around the M&A announcement, the abnormal return is 25.64% and on the announcement day itself already 17.99%. Previous studies find that the targets' shareholders realize an average abnormal return of about 30% (cf. Campa and Hernando, 2004) and therefore our specific results for the logistics service industry are in line with cross-industry studies. Panel B of Table 2 shows the results for the closest rival. It is assumed that the closest rival shows the most pronounced stock market reaction. The results show that in average rivals gain an abnormal return of 2.30% in the [-5;5] event window of the M&A announcement. On the announcement day itself the rivals' shareholders exhibit positive gains of 1.60%. This finding supports the Acquisition Probability Hypothesis, indicating that probability increases for rivals of targets to get targets themselves. We control this finding as we repeat the analysis for the three closest rivals of the target. Panel C of Table 2 shows the result for the three rival portfolio. In contrast to the closest rivals, the [-5;5] is not significant anymore. However, we still find positive abnormal returns in the [-1,1] event window and on the event day itself. The results indicate that besides the companies involved particularly the closest rivals earns positive abnormal returns in M&A deals.

**Table 2: Results for target and its rivals.**

Event window	ACAR	Median CAR	CAR >0	BMP (Z-score)	KP (Z-score)	CZ (Z-Score)	Sample size
<i>Panel A: Target</i>							
[-5;5]	25.64%	14.06%	82.76%	4.459***	4.115***	2.499**	29
[-2;2]	25.06%	18.98%	82.76%	4.994***	4.64***	3.997***	29
[-1;1]	22.72%	9.08%	86.21%	4.507***	4.189***	4.571***	29
[0;0]	17.99%	6.10%	82.76%	4.158***	3.836***	5.093***	29
<i>Panel B: Targets' closest rival</i>							
[-5;5]	2.30%	2.51%	65.52%	2.051**	2.354**	1.431	29
[-2;2]	-0.04%	0.46%	55.17%	0.217	0.568	0.162	29
[-1;1]	1.17%	1.98%	62.07%	1.135	1.454	1.365	29
[0;0]	1.60%	0.24%	65.52%	1.951*	1.910*	1.991**	29
<i>Panel C: Targets' average rival</i>							
[-5;5]	2.14%	0.91%	56.98%	1.775*	1.479	0.910	86
[-2;2]	1.10%	0.37%	53.49%	1.411	1.183	0.881	86
[-1;1]	1.31%	0.70%	56.98%	2.073**	1.908*	1.513	86
[0;0]	1.31%	0.20%	55.81%	2.364**	1.992**	2.030**	86

\*\*\*, \*\*, \* denotes statistical significance at the 1%, 5%, and 10% level, respectively

## CONCLUSION

In recent years, logistics service providers are undergoing fundamental changes in their business strategy. These changes led to a significant increase of M&As that are considered as important vehicles influencing a firms' business, product and geographic strategy. The rising number of M&A affects also the whole logistics service industry in terms of market disruption and innovation. Previous research, however, mainly focused on the companies involved in a transaction and neglects the fact that other companies could benefit from an M&A as well. Therefore, the presented study aimed at analysing the impact of M&A activities in the global logistics service industry. We show that targets benefit most in such transactions as their stock price gains about 25% around the announcement. However, we find that in contrast to other industries acquirers are able to benefit from M&A deals immediately showing positive abnormal returns. Most important, our results reveal spill over effects on the target side. Due to the increased probability that they can be targets themselves, the stock price increases around the announcement day. However, we do not find any evidence that M&A deals are beneficial for rivals of acquiring companies.

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# **INTERPRETIVE STRUCTURAL MODELLING OF ABSORPTIVE CAPACITY BUILDING WITHIN INTERNATIONAL JOINT VENTURES OF LOGISTICS FIRMS**

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## **Abstract**

### **Purpose of this paper:**

The purpose of this paper is to investigate how international joint ventures (IJVs) of logistics firms effectively build up the absorptive capacity. Despite logistics firms' growing formation of the IJV, there is fragmentation of understanding specific factors that influence their inter-firm interactions by building absorptive capacity in the logistics context. This research reviewed extant studies on IJVs of logistics firms and derived specific contributing factors to their inter-firm interactions by building absorptive capacity. There have been numerous contributing factors to absorptive capacity of logistics IJVs postulated by the extant research, but the interactions among the factors have not been fully explored. Thus, this research provide a holistic perspective of absorptive capacity building within IJVs of logistics firms.

### **Design/methodology/approach:**

Interpretive structural modelling (ISM) is a method to explain interactions of elements within a complex system (Warfield, 1974). This method analyses the orders and interactions among variables within a complex system in a systematic manner using directed graphs (Govindan et al., 2010). ISM helps to structure collective knowledge and generate a model of a complex system consisting of interactions of related elements (Alawamleh & Popplewell, 2011). This research identified twelve elements of absorptive capacity within logistics IJV. An application of ISM highlights the interactions and hierarchies of contributing factors to absorptive capacity by a graphical ISM-based model. It illuminates how absorptive capacity can be built up in the IJV settings of logistics firms and what elements should be specifically underlined for the capacity building within logistics IJVs.

### **Findings:**

The ISM-based model shed light on the four groups of twelve elements that can foster absorptive capacity of IJVs of logistics firms. The findings show that capabilities elements within Group 1 (Capability for knowledge acquisition, assimilation, transformation,

exploitation) are all interrelated, thus self-enhancing themselves. Group 2 (trust and commitment, accessibility of knowledge from logistics partners) highlights capacity building of IJVs is determined by inter-organisational collaboration. Group 3 (compatibility of knowledge source, cultural similarity, business relatedness) denotes the similarities of the business pertaining to the knowledge base between IJV partners of logistics firms. Group 4 (logistics partner's prior knowledge, organisational structure) possesses high driving power in this model by affecting other groups of factors, but their characteristics are slightly different.

#### **Value:**

Within the logistics domain, this research provides further theoretical insights and an ISM-based framework into logistics IJVs by building on the absorptive capacity and knowledge management disciplines.

#### **Research limitations/implications:**

This research provides implications for the managers of logistics IJVs. The findings suggest a holistic perspective on absorptive capacity building considering the interactions between the contributing factors within IJVs of logistics firms which offers a solid platform on which to base further studies. Top and middle managers of logistics IJVs can obtain useful lessons from this study. However, this research is not without limitations. Given the findings of this study are based on logistics IJVs, it limits the generalizability of the results toward other industries.

## **INTRODUCTION**

The purpose of this paper is to investigate how international joint ventures (IJVs) of logistics firms effectively build up the absorptive capacity. Despite logistics firms' growing formation of the IJV, there is fragmentation of understanding specific factors that influence their inter-firm interactions by building absorptive capacity in the logistics context. IJVs defined for the purpose of this study, are when 'two or more organisations share resources and activities to pursue a strategy' (Johnson, Scholes and Whittington, 2006: 353). IJVs present opportunities for partners to create and obtain appropriate knowledge, know-how and skills which plays a considerable role in IJV outcomes (Dong and Glaister, 2006; Inkpen and Beamish, 1997; Inkpen and Dinur, 1998; Liu, Ghauri and Sinkovics, 2010; Lyles and Salk, 1996) and can offer a channel for learning opportunities to learn skills and competencies from partners (Kwon, 2008; Tsang, 2002). By accumulating knowledge from partners, firms can gain new opportunities, and can find a source of organisational regeneration (Inkpen and Pien, 2006; Liu et al., 2010; Yli-Renko, Autio and Tontti, 2002) or strategic repositioning (Kipchillat, 2002). The capability to share knowledge effectively helps to sustain competitive advantage (Grant, 1996; Kogut and Zander, 1993; Noorderhaven and Harzing, 2009).

Continued poor performance of IJVs has increased interest in their management (Hyder and Ghauri, 2000), and the difficulty of managing IJVs has been found to lead to a high failure rate. This research reviewed extant studies on IJVs of logistics firms and derived specific contributing factors to their inter-firm interactions by building absorptive capacity. There have been numerous contributing factors to absorptive capacity of logistics IJVs postulated by the extant research, but the interactions among the factors have not been fully explored. Thus, this research provide a holistic perspective of absorptive capacity building within IJVs of logistics firms.

The main purpose of this research is to investigate how an IJV in the logistics sector build up the absorptive capacity and to investigate contributing factors to absorptive capacity building and their interactions in IJV contexts.

## **THEORETICAL DEVELOPMENT**

### **Absorptive Capacity of International Joint Venture**

Organisational learning is viewed as an element of an organisation's absorptive capacity and entails learning capability to assimilate knowledge (for innovation) and develops problem-solving abilities to create new knowledge (for innovation) (Kim, 1998: 508). Absorptive capacity is also viewed as a key aspect in the process of innovation of the firm (Cohen and Levinthal, 1990; Tsai, 2001) and as a result, it acts as a potential resource of competitive advantage in the market (Daghfous, 2004). Absorptive capacity is also linked to prior related knowledge involves basic skills and general knowledge available within the organisation at the most fundamental level (in the case of developing nations) but also possibly involves knowledge of the most recent developments in technology or science in a given area (in the case of developed nations) (Cohen and Levinthal, 1990; Kim, 1998). There is a positive relationship between accumulated prior knowledge and the ability to identify, assimilate and exploit new knowledge.

Together with the prior knowledge base element, intensity of effort is another key component of absorptive capacity (Cohen and Levinthal, 1990). The element of intensity of effort refers to the amount of work expended by individuals within organisations to solve problems or errors as applicable external knowledge becomes meaningless if no work is done to internalise it (Kim, 1998). The intensity of effort in learning how to solve problems is generally done by trial and error (Harlow, 1959) which strengthens interaction amongst individuals within an organisation which enhances knowledge conversion and creation at the organisational level. Thus, the concept of absorptive capacity can be interpreted as a path-dependent construct that builds on its prior knowledge and the intensity of effort, which in turn establishes the capability of the firm to acquire new knowledge (Cohen and Levinthal, 1990; Lane et al., 2001; Linyanage and Barnard, 2003). The higher the level of absorptive capacity means a more sustainable competitive advantage since as the organisation has developed and built its ability to adapt (Zahra and George, 2002).

#### **Four dimensions of absorptive capacity**

There are two different absorptive capacities within four dimensional construct: potential (acquisition and assimilation) absorptive capacity and realized (transformation and exploitation) absorptive capacity (Zahra and George, 2002). Within the potential absorptive capacity, it is made up of knowledge acquisition and assimilation elements (Zahra and George, 2002). Knowledge acquisition is viewed as a firm's ability to identify and acquire generated knowledge from external sources which is significant to its operations (Cohen and Levinthal, 1989; Zahra and George, 2002). Whereas knowledge assimilation capability implies the firm's processes and practices of analysis and interpretation of the information gained from external sources within organisation (Kim, 1998).

Within realized absorptive capacity, it is comprised of knowledge transformation and exploitation elements which operate as a function of the transformation and exploitation capacities. It refers to a firm's capability to refine and extend the processes and practices that make possible to unite both existing knowledge and the newly acquired and assimilated knowledge in order to let it be applied in new approaches. Knowledge exploitation of absorptive capacity is a firm's exploitation capability which refers to the capacity to apply and exploit new knowledge in product or services so that it leads the firm to obtain a competitive advantage and financial benefit from such processes. The importance lies on the application process of information (Cohen and Levinthal, 1989; Lane et al., 2006).



## **METHODOLOGY**

Interpretive structural modelling is a method to explain interactions of elements within a complex system (Warfield, 1974). Mental models of a complex system are often unclear and poorly articulated; ISM will transform them to a visible, well-defined and hierarchical model (Sage, 1977). In essence, this method analyses the orders and interactions among variables within a complex system in a systematic manner using directed graphs (Govindan et al., 2010). ISM thus can help structure collective knowledge and generate a model of a complex system consisting of interactions of related elements (Alawamleh and Popplewell, 2011).

This research aims to investigate absorptive capacity building within an international joint venture. There have been numerous contributing factors to absorptive capacity postulated by the extant research (e.g. Lane et al., 2006), but the interactions among the factors have not been fully explored. As a consequence, comprehensive and systematic understanding of absorptive capacity building is still lacking. An application of ISM will highlight the interactions and hierarchies of contributing factors to absorptive capacity by a graphical ISM-based model. It will also illuminate how absorptive capacity can be built up in the international joint venture settings and what elements should be specifically underlined for the capacity building.

The process of ISM shows slight differences across the literature. The flow diagram for ISM preparation is generally used to depict the process (Govindan et al., 2010; Alawamleh and Popplewell, 2011; Diabat et al., 2012), which is shown in Figure 1. There are eight common steps in undertaking ISM method as follows. Each step will be explained further in the analysis sections.

## **FINDINGS**

### **(1) Identification of elements in a complex system**

The first step requires researchers to identify and select elements within the subject complex system and relevant to the problem. This step can be achieved by primary data research (interviews, focus groups and etc.) or by secondary data research (literature review). For the purpose of the next step, the elements should be titled and numbered with clear operational definitions. This research thoroughly reviewed extant studies on international joint ventures and derived contributing factors to absorptive capacity building within joint ventures as discussed in the literature review. Table 2 demonstrates the 12 elements selected for this research.

### **(2) Contextual relationships between elements**

This is the most critical part which determines the interrelationships among elements. The contextual relationships between two elements can be stated by several types (Warfield, 1994), but this research adopted 'influence' relations by checking whether Element i leads to Element j. For this purpose, 66 pair-wise relationships among 12 elements were discussed within a focus group of five practitioners to ensure reliability and validity of the contextual relationships. Although there was initial disagreement with some pair-wise relationships, they reached a consensus after several rounds of discussions.

### **(3) Creating a Structural Self-Interaction Matrix (SSIM)**

The contextual relationships decided by the focus group discussion were converted into four symbols, which are:

- V – Element i leads to Element j, but not in the opposite direction;
- A – Element j leads to Element i, but not in the opposite direction;
- X – Element i and Element j are associated in both directions;
- O – Element i and Element j are not related.

A structural self-interaction matrix (SSIM) was then created by filling each (i, j) entry with one of these symbols as can be seen in Table 3. For instance, the symbol 'A' in the (1, 2) entry indicates the contextual relationship where business relatedness leads to compatibility of knowledge source.

#### **(4) Developing an Initial Reachability Matrix and a Final Reachability Matrix**

This step aims to generate binary matrices based on SSIM for further analysis. The initial reachability matrix uses 0 and 1 to represent four symbols in SSIM according to the following rules.

Rule 1: When the (i, j) entry is V, the (i, j) entry becomes 1 and the (j, i) entry becomes 0

Rule 2: When the (i, j) entry is A, the (i, j) entry becomes 0 and the (j, i) entry becomes 1

Rule 3: When the (i, j) entry is V, both (i, j) entry and (j, i) entry become 1.

Rule 4: When the (i, j) entry is O, both (i, j) entry and (j, i) entry become 0.

One of the benefits of using a binary matrix is to incorporate transitivity. Transitivity means an indirect relationship of two elements in mediation of another element; if A is related to B and B is related to C, then A is related to C. Even if an entry is 0 in the initial reachability matrix, it cannot completely exclude indirect relationships between elements. For instance, the (1, 5) entry is 0 in the initial reachability matrix. However, 1 can lead to 6 and, at the same time, 6 can lead to 5. In this case, a transitive relationship exists between 1 and 5. Likewise, all the entries with 0 can be investigated to check whether there is any transitivity in each entry. A final reachability matrix was created in reflection of these transitive relationships denoted by 1\*.

#### **(5) Partitioning levels using the Final Reachability Matrix**

The hierarchies of elements in a complex system can be captured by comparing the reachability set (Rs) and the antecedent set (As) of an element. The former denotes the set of elements which was led by the element whilst the latter means the set of elements which led to the element. The common elements in these two set constitute an intersection set (Is). The initial table of reachability sets, antecedent sets and intersection sets of 12 elements was derived from the final reachability matrix.

An ISM-based model allocates less influential but more dependent elements in the top hierarchy because general directed flows are upwards. The top level in the current set of elements can be decided by comparing the reachability set and intersection set of each element; if an element's Rs is the same as Is, the element becomes the top level. In Seven elements (5, 6, 7, 9, 10, 11 and 12) were found to be the top level. In the next round, the top level elements were removed from the table. After removing the seven elements, two elements (1 and 8) showed that their Rs was equal to their Is, thus became the second level. The subsequent rounds followed the same rule, creating four levels of elements in total.

#### **(6) Drawing a Digraph and the ISM-based model**

Based on the final reachability matrix and level partitioning, a digraph (or a directed graph) can be generated. It was drawn by allocating elements vertically according to their levels and then reallocate the elements considering their relationships with other elements. The elements were connected by arrows to indicate contextual relationships. At this stage, node numbers and transitive relationships were still considered in the model. The final ISM-based model, on the other hand, replaced node numbers with element titles and simplified transitive relationships to show the general directions, as shown in Figure 2. This model graphically shows that the contributing factors to the absorptive capacity building within an international joint venture can be effectively understood by the interactions of four groups of elements.

## **DISCUSSION**

The ISM-based model shed light on the four groups of elements that can foster absorptive capacity of international joint ventures. Group 1 consists of the capabilities required for absorptive capacity, which are knowledge acquisition, knowledge assimilation, knowledge transformation and knowledge exploitation. These capabilities are all interrelated, thus self-enhancing themselves by facilitating other capabilities. Absorptive capacity, in general, is represented by these four dimensions of capabilities (Zahra and George, 2002). They are closely related although they can be sufficiently discriminated by definitions and can contribute to different types of competitive advantage. The speed, quality and intensity of learning (acquisition capability) and full understanding of the knowledge (assimilation capability) can be a stepping stone for knowledge internalisation and conversion (transformation capability) as well as knowledge application and implementation (exploitation capability). This type of relationship was also agreed by Zahra and George (2002), which proposed that potential capabilities (acquisition and assimilation) will lead to realised capabilities (transformation and exploitation). In addition, new knowledge application requires more and better knowledge, which leads to the capability for broadening knowledge sources and enhancing the quality. To this end, realised capabilities can also foster potential capabilities. This ISM-based model confirms that the four capabilities are first order constructs of absorptive capacity while further showing mutual interactions among these capabilities. The focus group emphasised that the four dimensions are interdependent and become stimuli for each other.

## **RESEARCH IMPLICATIONS AND LIMITATIONS**

This research provides implications for the managers of logistics IJVs. The findings suggest a holistic perspective on absorptive capacity building considering the interactions between the contributing factors within IJVs of logistics firms which offers a solid platform on which to base further studies. Top and middle managers of logistics IJVs can obtain useful lessons from this study. However, this research is not without limitations. Given the findings of this study are based on logistics IJVs, it limits the generalizability of the results toward other industries.

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# PLANNING MULTIMODAL FREIGHT TRANSPORT OPERATIONS: A LITERATURE REVIEW

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## ABSTRACT

### **Purpose:**

Multimodal freight transport developed in the transportation sector as an alternative to unimodal transport faced with the challenges brought by the growing global demand for transporting goods. Multimodal transport is the transportation of goods using at least two modes of transport, usually door-to-door. The common transport modes include railways, maritime routes, and the roads. When restructuring and reconfiguring their logistics strategies, freight operators seek optimal operational plans to increase cost efficiency, improve customer service effectiveness, and enhance environmental sustainability throughout their entire supply chain network. In addition, collaborative planning enables multimodal transport providers (MTPs) in the multimodal transport chain to optimize mainly their operational plans.

A vast collection of scientific literature focuses on different objectives taking into account various limitations. For instance, in the context of short-term planning the challenge is to take real-time decisions considering the interests of all stakeholders. With the need for real-time decision making, this problem becomes complex, dynamic, and stochastic. Thus, the purpose of this study is to concentrate on the literature related to dynamic processes at the operational level from customer to consignee and provide a systematic classification of different planning and solution techniques.

### **Methodology/approach:**

Multimodal operational planning is investigated from two perspectives: modelling modal shift policy and planning of multimodal freight transportation. We describe the modal shift policies, discuss the advantages and barriers, and elaborate on the actors involved in this process and the factors affecting efficiency. Furthermore, we explain the importance of these factors for operational freight planning and denote the constraints in the planning problems. Finally, we present an illustrative example of a multimodal freight transportation network from customer to consignee.

### **Findings:**

Modal shift and operational planning lead to reduced lead times and operational costs, and also ensure convenient transportation according to the user's preferences. Studies on these issues can be examined with respect to the selection of non-dominated solutions and applicable routes determined based on the preferences of customers, pricing techniques, and revenue management methodologies.

### **Value:**

This study consolidates the knowledge in operational planning of multimodal freight transport from multimodal transport providers' point of view and addresses carbon dioxide mitigation issues as novelty. Moreover, it considers not only operational planning but also pricing and revenue management methodologies. It is a valuable reference to researchers who wish to comprehend entire operations in multimodal transport from different perspectives.

## INTRODUCTION

Multimodal transport is mostly preferred because of its flexibility compared to using a single mode and its environmental benefits towards sustainable transportation. The global environmental issues and carbon dioxide mitigation problems have induced the importance of maritime and rail transport since these transport modes play an important role in reducing carbon footprints (Pruzan-Jorgensen et al., 2010; SteadieSeifi et al., 2004). The efficiency of these modes increases even more with the right decisions and accurate system implementations. In other words, efficiency is directly linked with the construction of right conditions and choices of operational planning (Caris et al., 2008; Guajardo et al., 2015). The need for modal shift was examined and discussed in the literature through various measurement methods and several solution methodologies were proposed for achieving competitive advantages against unimodal transportation.

Multimodal transport network has inherently complex structure with numerous stakeholders. Its planning involves a multi-criteria decision making process where the objectives might consist of the minimization of cost, time, and/or carbon emissions as well as improvement of service levels and utilizations (Chang, 2008). MTPs establish horizontal collaborations across the same or different type of modes where it is necessary to gain benefits during the seamless transition of consecutive modal shift processes (Kayikci et al., 2012; Krajewska et al., 2008). Collaborative planning enables MTPs in the multimodal transport chain to optimize mainly their operational plans. On the other hand, the allocation of the benefits achieved through collaboration among the corresponding stakeholders and beneficiaries arises as a key issue to be resolved.

In this paper, we review the literature related to dynamic processes at the operational level from customer to consignee and provide a systematic classification of different planning and solution techniques. We describe the modal shift policies, discuss the advantages and drivers, and elaborate on the actors involved in this process and the factors affecting efficiency. Furthermore, we explain the importance of these factors for operational freight planning and denote the constraints in the planning problems. Finally, we present an illustrative example of a multimodal freight transportation network from customer to consignee. Our aim is to investigate the answers to the following three research questions: i) What are the key points of multimodal transportation, especially on the operational planning process? ii) What types of modal shift policy have been revealed in various studies? iii) Which solution techniques are proposed/applied in the literature from 2000 to 2017?

## METHODOLOGY

This literature review is conducted using a desktop research methodology; i.e. our study reviews articles related to multimodal transportation published in major academic journals and conference papers addressing multimodal transportation. Published papers are collected from 2000 to 2017. Few papers published before 2000 are excluded from this study since they have already been referred to in the recent literature and our primary objective is to shed light on the recently developments on the topic.

Firstly, a keyword search in major digital academic journal databases including ScienceDirect, INFORMS, Emerald Insight, Wiley Online Library, Taylor & Francis Online, and Springer has been performed. The principal keywords utilized are "multimodal transportation", "multimodal collaboration", "multimodal transport provider", and "planning multimodal transportation". Furthermore, the reference lists of selected articles have also been carefully exploited in order to form a large database of articles. Dispersion of these resulted articles in the databases and their types are shown in Table 1. In consequence, a total of 111 articles were gathered and classified under subtitles of Literature Review (LR), Case Study (CS), Mathematical Model, Modal Split, Sustainability (Green House Gases (GHG) Emissions), Collaboration and Revenue Management (RM).

This study may provide reference to researchers interested in several aspects of multimodal transportation.

<b>Database</b>	<b>LR</b>	<b>CS</b>	<b>Model /Plan</b>	<b>Modal Split</b>	<b>Collabo-ration</b>	<b>GHG</b>	<b>RM/ Pricing</b>	<b>Total</b>
ScienceDirect	7	1	16	9	6	4	4	47
Springer	4	-	8	-	2	1	2	17
EmeraldInsight	1	1	2	-	1	1	-	6
INFORMS	1	-	3	-	-	-	3	7
Taylor&Francis	4	-	1	1	1	-	2	9
Wiley	-	-	-	-	1	-	-	1
OpenAccess	2	-	8	1	1	-	-	12
Conference Paper	4	1	5	1	1	-	-	12
Total #	23	3	43	12	13	6	11	111

Table 1: Articles gathered from major digital academic journal databases

## LITERATURE REVIEW AND RESULTS

Multimodal operational planning is investigated from two perspectives: modelling modal shift policy and planning of multimodal freight transportation. The section on the modal shift focuses on evaluating modal shift transport policy measures and aims to raise awareness and consideration towards the change of transportation mode as a transport policy option. It also includes various collaboration settings throughout the freight flow from the origin to the final destination. The section on the operational planning discusses practical planning techniques and case studies that deal with the implementation of multimodal transport at the operational level in order to assess the feasibility of a modal shift.

### Modal shift policy

The actors of the operational side of international multimodal transport are shippers, multimodal transport providers, and freight forwarders. A shipper is the company that is responsible for initiating a shipment and who may also decide on the total freight cost. This type of member has control on the supply chain and is capable of stabilizing the financial part improving their cost levels, service capabilities, and/or environmental footprint (Cruijsen, 2012). MTPs are the companies that can offer multimodal transport operations within the framework of national and international trade and transport practices in the sector. Freight forwarders play an important role in sea routes, acting as agents of shippers who are less popular to reach customers (Lu, 2013).

The freight transport network consists of three essentially components including pre-haulage, main-haulage, and end-haulage, as illustrated in Figure 1. While pre-haulage and end-haulage are usually provided by road transport for short distances, the main-haulage is carried out by using other types of transport such as rail, sea, and inland water for longer distances. It is known that multimodal transport is competitive during main-haul transportation, if the transported distances are beyond 300 km which is longer than one day of trucking (SteadieSeifi et al., 2013).

In this transport chain, cooperation can be established between carriers, shippers, and all MTPs. Different forms of collaboration, both vertical and horizontal are important for the competitiveness of companies. The system where the operators and shippers work together is considered as the most suitable combination of these collaborations; however, it is also the most difficult system to establish and maintain despite being the most effective. The cost components of this system should be identified and the distribution of income should be arranged carefully since it is necessary to consider revenue and cost allocations, risks and involvement of each operator. Describing and measuring the performance of different stakeholder in the collaboration are one of the

key points in allocating revenue. At the core of their partnership lies the fact that each shipping or transport company has to reduce or share their costs while they are satisfying the demands of the shippers (Ergun et al., 2007). These horizontal collaborations reduce costs and increase productivity. A good example is the replacement of empty container shipments with those that are filled in a coordinated manner, and the transfer of loads in rapid coordination instead of waiting for the storage and landfilling. On the other hand, time to share information and mutual self-sacrifice are required to establish and maintain mutual trust and transparency among collaborative stakeholders (Caris et al., 2008).

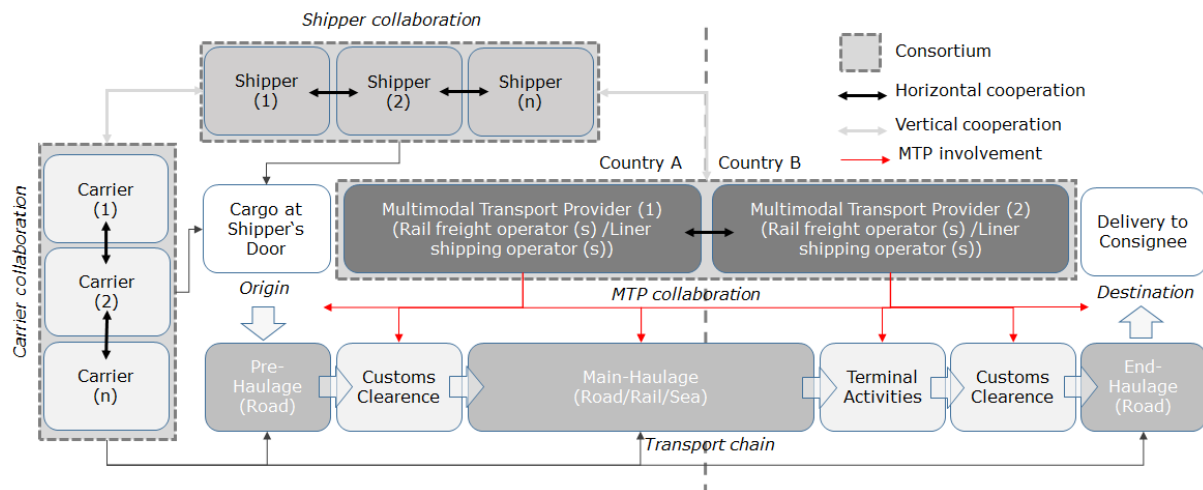


Figure 1: Freight Transport Network, MTP Collaborations

Globalization and improvement in the communication facilities have encouraged the multimodalism and the latter is recognized worldwide as an efficient way to reduce logistics cost exploiting different operational methods. To illustrate, collaboration between the carriers and also between the MTPs is an important example of cost saving approaches. Through collaboration, MTPs decide together on which shippers' reservations can be executed, postponed, or cancelled by analyzing different slot allocation scenarios. If they accept the reservation of a shipper, they arrange all the necessary slots from both vessels and trains simultaneously on the main-haul.

In order to be competitive in the transport sector, service providers should be more flexible favoring multimodal choices such as combination of road, sea, rail, and air. At this point, the transport service provided should be preferable by shippers and also multimodal transport providers (MTP) should arrange their services environmentally friendly. Flodén et al. (2017) gathered key factors contributing to the decision making process such as cost, quality, reliability, transport time, and sustainability of the system and environment. In general, reduction of carbon dioxide (CO<sub>2</sub>) emissions through the terminal network design and operations are the objectives of the governments and CO<sub>2</sub> pricing can be regulated accordingly as a part of the cost structure (Zhang et al., 2015).

In multimodal freight transportation, uncertainties and randomness always take place throughout the freight flow process. This complexity increases the importance of reliability, smart disruption management, and sustainability of the operation while determining the decision criteria (Huang et al., 2011). Ferrari (2015) concluded that dynamic parameters of modal split of a multimodal freight transport system between origin and destination are gathered under three subtitles. These are the increase rate of overall freight flow, the delay, and the dynamic cost functions of different modes. Since the multimodal network is complex and dynamic, determining dynamic characteristics and modeling modal split are useful to forecast overall freight flow and to decide accordingly on the unknowns of future time periods.



## Planning multimodal freight transportation

The operational planning basically consists of deciding on which freight to accept or reject for routing and planning the overall route to transport selected vessel, train, and trucks. Freight mode choice is one of the most problematic issues while preferring the multimodal transportation. The main drivers of the decision making process are cost, transit time, reliability, and frequency of the service. Frequency is usually preferred by manufactured good sectors while temporal reliability and security of the service are mostly preferred by automobile manufacturers and exporters (Shinghal et al., 2002; Cho et al., 2012). In addition to these, constraints related to the capacity of modes and nodes, pickup and delivery times should also be incorporated into the model and the associated data should be collected and gathered for taking the necessary actions. The selection of the non-dominated and applicable routes to construct multiple Pareto solutions pool is achieved via various mathematical models. The subsequent phase is determining the best route according to user's preferences among the optimal alternatives.

Each mode of transportation has its own characteristics, limitations, similarities and differences, advantages and disadvantages. Planning each of them separately requires different techniques, but planning them together within a systemic framework coherently needs more complex techniques and models. Various operations research techniques are widely utilized in order to improve the design and operations of multimodal networks (Gorman et al., 2014). Furthermore, transport solutions have to be realizable, flexible, easy to apply, reliable, transparent, and efficient to cope with the preferences of different decision makers operating in the multimodal transport network (Caramia, 2009). The solution techniques for operational planning are mainly classified under the following five categories: direct solution methods using linear programming; stochastic solution methods using dynamic programming; heuristics; decision analysis models for mode choice, and other methods such as survey and simulations.

In general, minimizing cost and transport time are the two main objectives that service providers and researchers have looked after. In addition to these, awareness towards environment, willingness to pay, and service quality are the additional objectives and constraints to satisfy. Multi-objectivity requires using a combination of several methods. The crucial point is to choose appropriate model type(s) after the examination of the acquired information about the system. Deterministic models give fairly enough discrete values in order to use in planning but they do not cover the reality completely; so, some dynamic properties and randomness in the data requires stochastic models. Besides these, probabilistic models are utilized to come up with estimations directly such as the mode choice and shipment size (De Jong et al., 2016). Studies implementing different solution methodologies are summarized in Table 2.

As a transportation network, multimodal transportation carries external negativities associated with environmental and societal issues. For instance, Demir et al. (2015) classified these negativities in five groups including air pollution, greenhouse gasses, noise and water pollution, congestion, accidents, and land use. They point out the importance of being aware of these negativities of each transport mode and inventing the model to measure the tradeoff between disadvantages and users' preferences.

The capacity management during routing and scheduling is crucial success factor for the sustainability of the multimodal transport, especially in sea-rail legs. The capacity of freight vessels and trains should be utilized at least at a rate of over 70% per trip in order to maintain profitability (Kayikci, 2014). At this point, revenue management and pricing strategies may help decision makers, principally MTPs; increase their profit by augmenting the capacity utilization rate. The main goal of revenue management is to find the maximum freight travelling along each possible leg in order to maximize the revenue by minimization of costs, allocation of slots, and dynamic pricing. Kayikci demonstrated that the application of different fare and shipper classes may help achieving up to 2%

increase in revenue per combined trip while the minimum capacity requirements are fulfilled. This application is required due to different arrival/booking times of shippers. Contacted shippers are subject to an annual fixed price, shippers who book their slots during the booking time may be subject to another fixed price, and finally the needs of urgent customers may be supplied with more complex pricing strategies. Price discrimination may be applied to the different contents of containers or semi-trailers since hazardous and perishable products require additional equipment and care.

<b>Solution Techniques</b>	<b>References</b>
<b>Direct Solution (MILP, LP)</b>	Cea et al, 2003; Aifadopoulou et al, 2007; Chang, 2008; Kim et al, 2009; Lu et al, 2010; Puettmann et al, 2010; Flórez et al, 2011; Ayar et al, 2012; Bierwirth et al, 2012; Sergio et al, 2012; Bhattacharya et al, 2014; Sun et al, 2015; Verdonck et al, 2016; Baykasoğlu et al, 2016; Corman et al, 2017
<b>Dynamic, Stochastic, Two-Stage</b>	Cho et al, 2007; Agarwal et al, 2008; Bock, 2010; Cho et al, 2012; Kalinina et al, 2013; Ferrari, 2015; Hao et al, 2016
<b>Heuristics, Meta-Heuristics</b>	Yamada et al, 2009; Caramia et al, 2009; Vanovermeire et al, 2014; Kengpol et al, 2014; Gkiotsalitis et al, 2015; Zhang et al, 2015
<b>Mode Choice, Predictive Analysis</b>	Gelders et al, 2003; Frejinger et al, 2009; Macharis et al, 2011; Huang et al, 2011; Lu, 2013; Masiero et al, 2013; Arencibia et al, 2015; Bovy et al, 2015; Kucukaltan et al, 2016; Combes et al, 2016
<b>Survey, Simulation, Others</b>	Shinghal et al, 2002; Luo et al, 2003; Kim et al, 2011; Hanssen et al, 2012; Kelle et al, 2016

Table 2: Classification of solution techniques of operational planning models

## ILLUSTRATIVE APPLICATION

According to commercial and governmental agreements between Turkey and European countries, international multimodal freight transport is currently carried out. As the rail transport system in Turkey is not developed and as efficient, the freight is brought to the ports by road during pre-haulage and then transferred to the appropriate ports in Europe on RoRo vessels by sea. The freight coming to the multimodal hub or terminal is loaded to the RoLa or other type of trains and is transported to the destined points in various European countries. If the destined point does not have RoLa or RoRo terminal, post-haulage is conducted by road.

The example in Figure 2 illustrates the alternative routes from Istanbul to Kiel. The analysis is carried out using the information from the website [www.intermodallinks.com](http://www.intermodallinks.com). From Istanbul, two MTPs are available to conduct this multimodal transportation, Ekol Logistics and U.N. Ro-Ro. Both of them have vessels travelling from Istanbul to Trieste port approximately in 60 hours and their frequency is 4 times per week. Ekol has its own RoLa 64 times per week from Trieste to Kiel (28 hours) directly. Alternatively, it offers its own services to Cologne (24 hours) 640 times per week and which can be combined with dedicated rental trains to Kiel. U.N. Ro-Ro also rents dedicated trains from Trieste to Kiel. The trip takes less time (approximately 4 days) but the frequency is very low, only once every week. If the shipper prefers more frequent sea-rail legs, U.N. Ro-Ro can transport the freight from Trieste to Wien or Salzburg, and then continue to Hamburg which is located just one hour post-haulage road transport from Kiel. In this option, the frequency increases to 3 times per week but the total transport time increases as well, to 6 days.

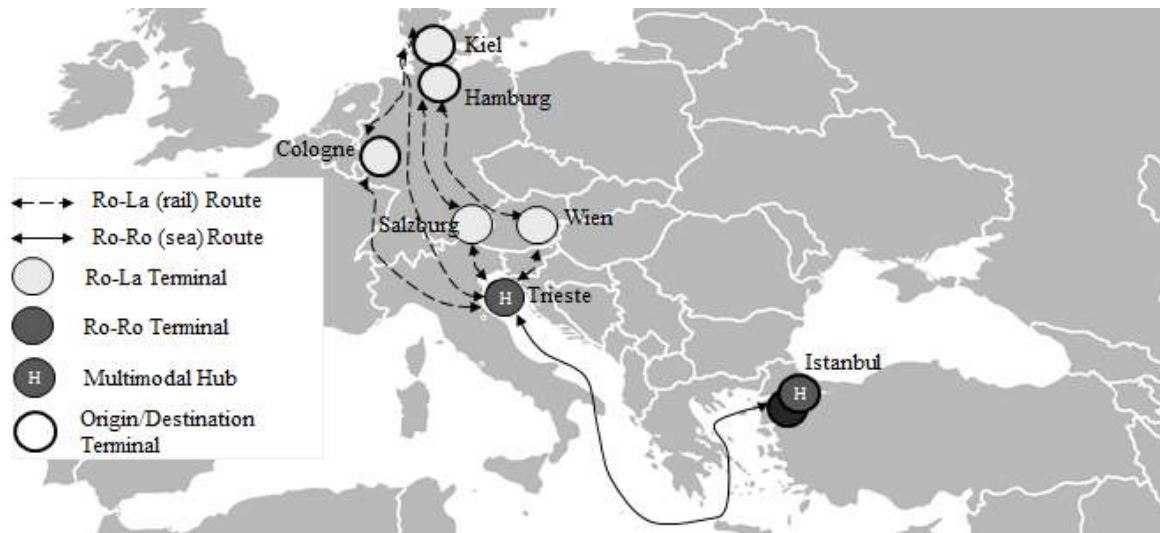


Figure 2: An Illustrative example of multimodal transport from Istanbul to Kiel

The increase in total transport time is caused by the increase in the number of modal changes since the terminal operations require extra time for loading and unloading, and may also raise the cost. The route planning and selecting the optimal alternatives are conducted by exploiting different mathematical models and the decisions are made by customers, mainly shippers upon their decision criteria such as time, cost, frequency, number of modal shifts, CO2 emissions, and reliability of modes.

## CONCLUSION

Although the multimodal transport sector is a transportation business driven by diverse equipment and vehicles that require large investments and whose continuity of revenue is largely uncertain due to the changes in the market demand, the advantages of multimodalism are still increasing day by day. Along with the studies carried out and efficient planning of operations, multimodal transport has become more preferred option in logistics. Moreover, it is rewarding as it reduces the emission of harmful gases, eases the traffic congestion, and prevents unnecessary waste of money and time.

In this paper, we discussed the key points of multimodal transportation and important actors in the freight transport chain. We also highlighted the requirements of modal shift and the objectives of operational planning. Solution techniques are classified and exemplified for further practices. With the light of the information provided, the next step may address the development of the necessary solution methods according to the available data. The crucial points for the future studies are to consider the system as a whole and come up with a compromising mathematical model(s) which may involve multiple objectives. The model should be compatible with the real-life applications by acting rapidly upon changes. To achieve optimal results, appropriate solution methods that are available in the literature can be applied as well as intuitive, meta-heuristic algorithms suitable to the obtained data can be designed and implemented.

## ACKNOWLEDGMENTS

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**A complete list of references which are denoted in tables will be provided upon request.**

# TRANSPORTATION SYNERGIES IN INBOUND LOGISTICS FLOW AT AUTOMOTIVE ASSEMBLER PLANT

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## Abstract

Transportation costs are responsible for a large portion of the logistics cost. This is particularly important in companies that are located in peripheral countries. Valuable cargo companies under these conditions tend to receive more often, which easily leads to LTL. The purpose of this paper is to assess alternative scenarios for reduction of transportation cost for a car assembler in Iberia, taking into account the development of a collaborative software to handle sharing process at low prices and risks, attempting a somewhat flexible solution in a rigid industry. The proposed approach looks for logistic data flows and identifies aggregation solutions for inbound flows using rail solution and sharing space with other players to balance outbound traffic.

## Introduction

The Collaborative Broker is a goods aggregation platform that allows participation in the sharing transportation market, where synergies among several logistics departments are suggested towards low cost transportation of their goods. Sharing of cargo with other companies to achieve FTL is becoming popular and leads to transportation savings (Rushton, 2017).

The basis for this work was the logistic supply chain from Volkswagen-Autoeuropa (V-AE) cost reduction needs due to their geographic location. V-AE is a car assembler plant located in Portugal belonging to the Volkswagen Group. Each assembly plant tries to compete internally for the assembly of new models and costs are the main driver in the decision process. V-AE has reduced labour cost when compared to other European plants but logistics costs is higher. The Company's inbound material flows are originated in central Europe and the main transportation mode is truck. There is a large gap in volume between inbound and outbound flows as only empty racks are in the outbound flow). Eventually with other types of mechanisms the waste in the outbound volume could be minimized. Also, the motivation for this work comes from the fact that out of the total plant costs the most significant share besides materials comes from the logistic framework and material handling: Material 80%, Logistic 7%, Manpower 7% and Energy 6%. Nowadays the tendency in the automotive industry is that these 7% of logistic costs will to increase due to: 1) Increase of "Carry over parts" (COP) parts in the vehicles that are produced in V-AE, and consequently the increase of the distance from V-AE to those suppliers. This is due to the fact that V-AE is not the plant that consumes the biggest amount of the requested parts, making sense to have the supplier's parts placement closed to those ones; 2) Supplier's displacement to East Europe countries and to China due to production costs, increasing the distance from V-AE to those new locations, resulting in higher logistic costs. In the External Logistic Operations the problem is that there is not enough outbound volume in the trucks leaving V-AE compared to the inbound volume. The amount of money spent in External logistic operation is equally divided between the transportation to V-AE and the local logistic operations. This paper focus only on transportation costs, where two

types of truck trips can be considered: 1) Round trip – Inbound and outbound trips together; 2) Single trip – Only Inbound trip and this trip has high potential for a collaboration approach with others nearby companies.

The aim of this paper is to propose of a software solution identified as a collaborative broker that helps registered companies to share transportation resources and identify opportunities for train and maritime transportation, when high levels of transportation needs are achieved.

Basically this case study looks for: 1) What is the geographical distribution from suppliers; 2) Which are the routes truck performed; 3) Gather information about train and marine transportation; 4) What is the inbound / outbound volume associated to the currently existing truck; 5) Matching approach towards sharing.

### Case Study: current transportation scenario

Figure 1 shows that the main concentration of V-AE suppliers is in Germany, representing 51% of the total, followed by Spain with 14% and Portugal with 10%. This value represents annual percentages taking into account year 2013 data. This process was performed based on geo-referenced suppliers and associated volume.

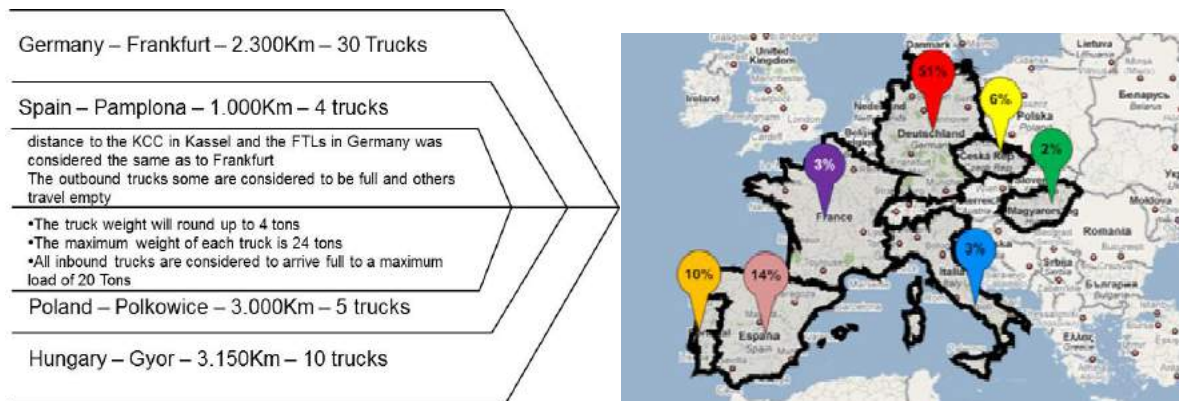


Figure 1 – Visual representation on percentage of suppliers per country

In terms of transport type form suppliers the following options are considered:

1. FTL – Direct Relations. In the case study transportation is done directly from the supplier to V-AE.
2. KCC – Consolidation Centre. Parts from several different suppliers, eventually from different countries, are joined together at a consolidation centre and then shipped to V-AE. V-AE manages two consolidation centres in Germany: one in the north in the area of Kassel, more specifically in a town called Baunatal, and another in the south of Germany in Kornwestheim, near Stuttgart.

A data analysis using several years data is available (from 1995) to identify transportation potential synergies and identify train transportation, based on: 1) supplier geographical location; 2) production volume; 3) defined stock level; 4) transportation mode (airplane, truck...); and 5) volume occupied by the required number of parts. Per supplier it is established a standard frequency of parts arrival to V-AE. This standard frequency can be changed at any time if a special event occurs. Figure 2 (B) shows the characterization of the suppliers by transport time. It can be seen that 53% of V-AE suppliers take 7 days to transport their components. These are followed by the suppliers that take 4 days (12%) and 9 and 8 days, respectively 9% and 7%.

Figure 2 (A) shows that 65% of V-AE supplier's send their production through the two Consolidation Centres in Germany (KCCs). Only 2% of the suppliers generally characterised as FTL's send their production directly to V-AE. From Central Europe, it is mainly components from other VW plants that appear as supplied to V-AE (engines, hot forming parts, etc...). The remaining 37% are generally characterised as GEBIET (purchased by the company at the door of the supplier, Volkswagen concept).

In terms of KCC there are 8 trucks/week of inbound and 2 trucks/week of outbound (this average value from 10 years data taking into account two production shifts).



In terms of FTLs from central Europe there are around 22 trucks/week of inbound and 10 trucks/week of outbound, 10 trucks/week of inbound and 5 trucks/week of outbound from Hungary, 5 trucks/week of inbound and 2 trucks/week of outbound from Poland; 4 trucks/week of inbound and 1 truck/week of outbound From Spain; and 17 trucks/week of inbound and 10 trucks/week of outbound from Portugal. Available for the collaboration process it is possible to consider (only inbound): 18 trucks/week from Germany and Spain, 3 trucks/week from Poland, 1 trucks/week from France and 5 trucks/week from Hungary.

The output of this characterization process of the V-AE suppliers was based on:

1. Its geographical distribution: 1) 30 different countries; 2) 4 different continents
2. The main transportation flows: 1) 51% arrives from Germany; and 2) 14% arrives from Spain
3. V-AE standard transport days: 1) 53% of the suppliers with 7 transit days; 2) 12% of the suppliers with 4 transit days
4. V-AE stock's level; 1) 2 days (pending on type of part affected)

Taking into account these guidelines and production volume a software was developed to identify volume of swaped bodies (see section 4).

Supplier characterization by "Transport Type"

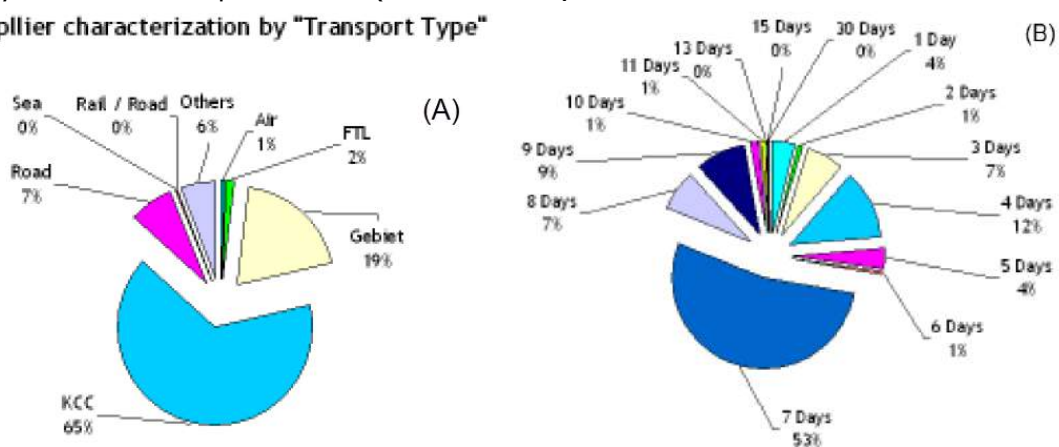


Figure 2 - "Transport type" by specific type of supplier (A) and by transport days (B) (source V-AE)

### Road Versus Rail Transportation Modes

Evolution of Transportation in the European Union - In the past three decades, the railroads share of all freight transport in the EU has dropped from 21% to less than 8% - compared with 40% of all freight in the United States - according to the UE transportation officials (Blum, 2005). Still, that trend may be starting to reverse. Europe's roads are increasingly saturated and environmental concerns are putting pressure on road transport. EU transport ministers intend to review the road transportation market amid calls for a more levelled playing field among different forms of transportation. Rail freight, measured in metric ton-kilometres, raised 2 per cent EU-wide in 2004, with the most solid growth in Germany and the Netherlands. But it continued to fall in France, where a three-year restructuring plan, started in 2003, is shedding marginal clients in a bid to cut losses, which had reached 15 per cent of turnover (Eurostat, 2013). Delays are the major deterrent. According to EU data, in 2001 less than 48% of trains ran on time (EU, 2001). That number raise to 65 per cent in 2004, but 7 per cent was delayed for as long as 24 hours (EU, 2014). When comparing this to the 95 per cent - 98 per cent punctuality record of road transport, there is a lot of catching up to do. Speed is less important for freight operators than on-time delivery (EU, 2014). One can say that "Reliability is the key!". Crossing borders are the biggest source of delays, involving different voltage and signalling systems, rules on permissible loads, safety and working practices. Railroad tracks in the Baltic States, Spain and Portugal are wider than those in the rest of Europe and locomotives have to be changed for different types of networks. Railroads could be safer, less polluting and more suitable than roads for transporting large quantities of goods over long distances. But Europe's problem is that its train freight services were designed to serve domestic markets. According to data from INE (Portuguese National Institute for Statistics), transportation by rail road represents only 3.2% of the total weight transported in Portugal in 2007, against

96.8% transported by road (EU,2014). International data also shows the same trend, with a value of 2.6% of total weight transported by Rail, against 97.4% using Road means of transportation (Eurostat, 2016). Table 1 resumes freight transportation evolution in EU (Eurostat, 2016).

Table 1- Freight transportation per mode evolution in EU, from (Eurostat, 2016).

Freight transport in the EU	2000	2012	Variation 2000/2012
Total tkm (billion)	3513.3	3768.1	+7.3%
Road	1521.6	1692.6	+11.2%
Sea	1322.8	1401.0	+5.9%
Rail	405.5	407.2	+0.4%
Inland Waterway	133.9	150.0	+12.0%
Oil Pipeline	127.1	114.8	-9.7%
Air	2	3	+50%

Characterization of Rail operators - The two main operators working in Portugal for rail transport are CP Cargo and Takargo. CP Cargo is a company constituted with public capital, whereas Takargo is the first private operator working this type of service in Portugal. Table 2 shows the main operators involved in this operation and the main characteristics to consider in rail transportation process.

Table 2- Rail Freight operators and main characteristics

	Portugal	Spain	France
Infrastructure (maintenance, construction, management of rail traffic, slots)	REFER	ADIF	SCCF
Public Operator (management of transport service)	CP	RENFE	DB
Other private operators	Takargo and wheels	Comsa and Transfesa	SAR; Wheels and Transfesa
Gauge	1668mm	1668mm	1435mm
Weight (allowed)	800 Ton	900 Ton	
Length (allowed)	550 meters	450 meters	Until 750m

Figure 3 (left side) presents the Basis Concept with main locations, expectancy for transit times between main locations and key points of the operation. This was the basis for this service were based on production amount 3 to 4 trains were required per week, therefore around 180 swap bodies of 3 meters high (usable space). This would represent around 5000 transports of trains between Portugal and Germany. Rail transportation is advantageous over road transportation for distances greater than 550 Kms. For the case of V-AE the proposed solution is to implement Intermodal trains including swap bodies that contain the materials and will introduce a new door to door delivery integrated concept. Swap bodies take advantage of the large number of trailers used to carry standard ISO containers. The design of swap bodies and roller container is optimized to minimize empty weight, saving on trucking fuel cost (less dead weight to be transported) and cost of built reloading terminals. In case of a failure or delay this concept can be used to transfer cargo to truck. Based on the associated tracking solution (see section 4) it is possible to follow materials and check of inefficiencies with the analysis of past data. A SWOT analysis of the Train project is also provided in Table 3. Other analyses are also performed, as for example the Investment that is needed from the transportation company, in terms of quantity of transport material needed, infrastructure and respective costs analysis.



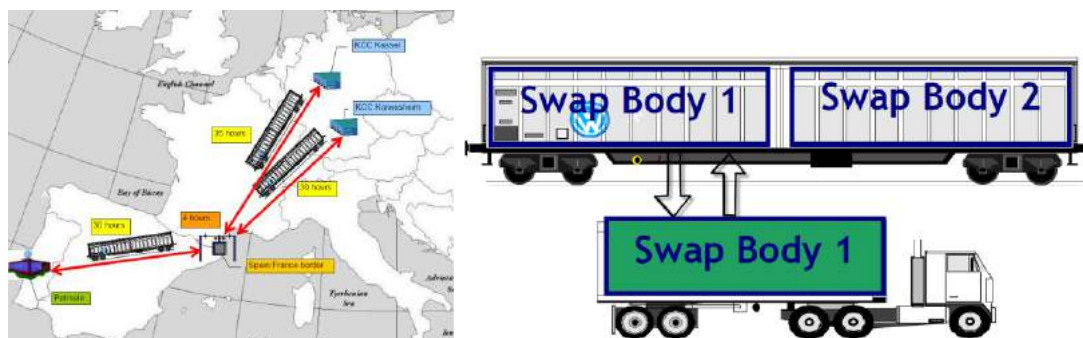


Figure 3 - Concept presentation of Transit times between main locations, (left side). (One-Way trip approx. = 70 hours). Figure right side the Swap Body concept, to perform easy changes of transportation mode: Train-Truck and Truck-Truck.

Table 3: SWOT analysis of train transportation option

<b>Strengths</b> <ul style="list-style-type: none"> <li>• Volume- one train replace 26 to 32 trucks</li> <li>• Less Co2</li> <li>• Lower costs for long distances (more than 500km)</li> <li>• No traffic delays and does not depends on weather conditions</li> </ul>	<b>Weaknesses</b> <ul style="list-style-type: none"> <li>• No standardization at rail system in Europe and transfers time between France and Spain</li> <li>• Handling costs</li> <li>• Consolidation platform required</li> </ul>
<b>Opportunities</b> <ul style="list-style-type: none"> <li>• EU target goal to reduce Co2 emission</li> <li>• Increases of fuel prices and transportation restriction</li> </ul>	<b>Threats</b> <ul style="list-style-type: none"> <li>• Road solution is reliable</li> <li>• Volume need means less flexibility</li> <li>• Jiga trucks soon available in Europe</li> <li>• Missing time frames for goods transportation</li> </ul>

### Collaborative Broker Software and Methodology

The impact study is focussed on relevant problems and drivers of the ICT R&D in the large-scale deployment of the mobility solutions. The aim is to meet the scope of policy intervention taking into account the main general and specific objectives mentioned. Wherefore the methodological concept underlying the work plan structure has a strongly inductive approach and is based on empirical evidence from data manipulation of transportation data available from 10 years. The dynamic process considered has four main steps (Input, Process, Output representation and tracking process through the use of low cost BLE (Bluetooth low energy) sensors). This process is presented in Figure 3 (right side) and followed Yin's (2009) recommendations. Also temperature, humidity, door open can be implemented in a Bluetooth transmission to a master, with the big advantage of no cable. This process only required batteries that can be used for periods of 2 to 3 years. The data collected was systematized taking into account weight, volume, date, transit time and geo-referencing. Process phase has the objective of content analysis and assessment for the improvement. To simplify the process each supplier uses swap bodies and price is based on this. The system alerts for train schedules and available capacity taking into account the need of more volume in the outbound flow because V-AE has more inbound than outbound. The proposed software allows the: 1) Characterization of the current transportation network from V-AE; 2) Characterization of the current transportation network from partners within the empty outbound volume of V-AE; 3) Create a truck synergy scenario for both parties, because the interface is available to inform potential clients are register their needs in the platform; 4) Create a potential Train scenario based on the truck synergy scenario using the same approach identified for item 3). In a first phase potential partners were contacted directly and invited to upload their transportation needs to the system. Example of these suppliers are: 1) Colepccl; 2) Corticeira Amorim; 3) Grohe; 4) Karmann Ghia; 5) Simoldes; 6) Labsfal, among others.

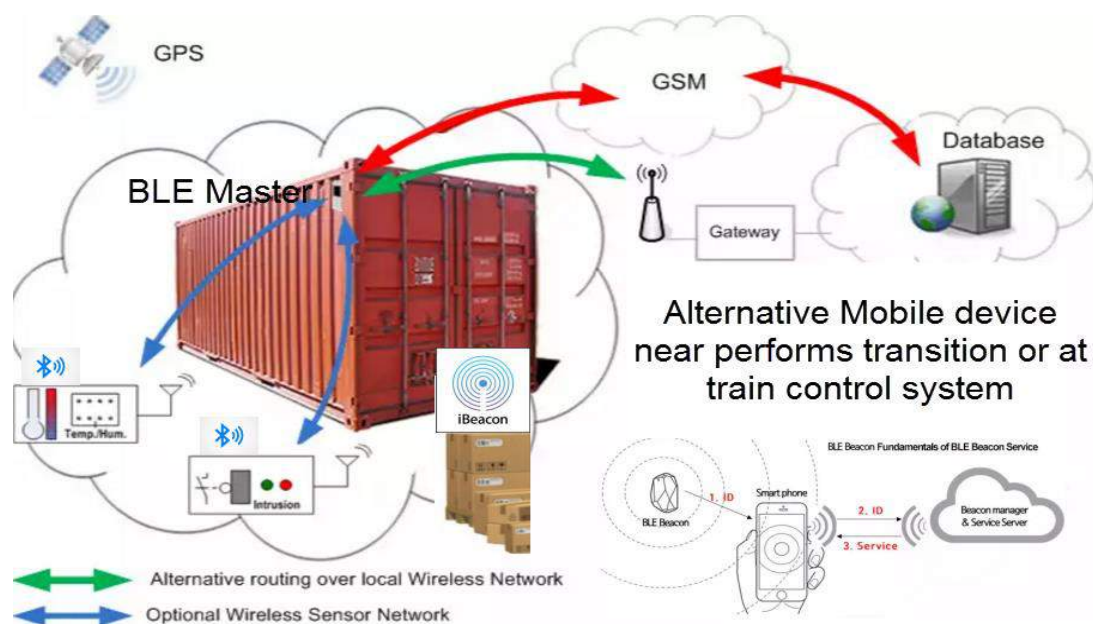


Figure 4 – Trucking Process based on low cost BLE

The suppliers that agree to join the project need to fill the following information in the system: 1) For which countries does your company export?; 2) For each country, which are the place(s) of loading?; 3) For each country, which are the place(s) of unloading?; 4) For each country, what is the frequency of trips?; 5) For each country, what kind of material is sent (plastic, steel...)?; 6) What kind of packaging is used (steel, card, plastic, wood...)?; 7) For each destination, which are the weights, dimensions and average volumes?; 8) Are there any special requirements or limitations for the transport, loading or unloading? Matching programming process was: 1) Country - In this work only companies operating in Portugal were considered; 2) Exporting activity - In this work only companies with significant exporting activity were considered otherwise the partnerships would not be possible; 3) Exporting destinations - In this work were considered companies exporting to central Europe because V-AE receives most of the material from there; 4) Type of materials/products - In this work several different type of materials/products were considered like metal, plastic, cork, rubber, fabrics, clothes, shoes (transport of animals and food were excluded); 5) Type/size of packaging - In this item there was not any restriction as the cargo can be transported in mega-trailers, the type of truck mainly used by the logistic operators working with V-AE. So it was considered pallets, boxes, racks, etc.

## 5- Major findings

**Corticeira Amorim** - Amorim & Irmão and Amorim ACC are exporting respectively: Cork stoppers for wine cellars, transported in FTL and other different materials. Courier transports are being used, as for example UPS, TNT and DHL French market. To the French market material is also sent from Amorim & Irmão to Bordeaux (Dept. 33). A large quantity goes in FTL. Some material is also Capillary distributed. Volumes are variable, with a frequency of 2 to 3 trucks per week to dept.66 and with a frequency of 1 to 6 trucks per week to Dept.33. Poland market (Krakovia) – 2 trucks per week. Hungary market – some volume, but is a difficult market due to the fact that it is a hard country to work in site, with 5 to 6 deliveries representing 1 full truck per week. German market - Until 2007 it was the best Truck market, contributing with 48% of sales volume. Amorim group uses the following packaging: Filmed Europallets; Belted Europallets; Boxes and Bags. For the “floor” dimensions are 1,2x1x1m, with a weight of 800Kg, Boxes have the following dimensions: 1,2x1x2m, Cork Bags have dimensions: 1,2x1x1,75m or 1,2x1x2,8m, Materials for Containers have dimensions: 1,2x1x2,5m, Isolating materials have dimensions: 1,2x1x2,2m.

**Simoldes** does have following destinations: 1) France (Vallenciene); 2) Germany; 3) Poland (from Simoldes Portugal to Simoldes Poland); 4) Hungary (goes from Poland to

Hungary); 5) Spain (Barcelona area). Simoldes they are always interested in FTL rather than "grouping". The transporters are Graveleau - Dasher (Germany) and Gefco from PSA group, which is a challenge for the management of VW empty racks / boxes, that requires a very tight control from Simoldes in order not to lose money due to defective or lost racks.

**Colep CCL Portugal** - Embalagens e Enchimentos, S.A. is engaged on the production and sale of metal and plastic packaging products in Europe. It operates as a contract manufacturer of personal care, cosmetics, over-the-counter pharmaceuticals, and household products. The company's product line includes aerosol packaging products, such as tinplate aerosols; general line packaging products, including cylindrical, conic, and rectangular cans for paints and varnishes, lubricants, olive oil, and biscuits; and injection molding products consisting of aerosol caps, handles, and closures, as well as other plastic parts.

**Grohe AG** is Europe's largest and the world's leading single-brand manufacturer and supplier of sanitary fittings, holding roughly 80% of the world market. As a global brand for sanitary products and systems, Grohe is setting standards in quality, technology and design.

**Karmann-Ghia de Portugal** was established in 1992, taking full advantage of the competitiveness and opportunities provided by the automotive industry in Portugal. Karmann-Ghia de Portugal is specialized in the production of seat covers in fabric and leather for the automotive and aviation industries.

Table 4 provides additional information about Grohe AG and Karmann-Ghia de Portugal.

Table 4: Characterization of Karmann-Ghia de Portugal and Grohe

	Country of Destination	City/ place of load	Nº of pallets (per week)	Weight (ton/week)	Volume (m3/week)
Grohe	Germany	Hemer	6	48	
Karmann-Ghia	Germany	Kitzinger	2	0,3	6
	Czech Republic	Dubice Liberec	22	6,2	57
	<b>Total</b>		<b>24</b>	<b>6,5</b>	<b>63</b>

Based on these inputs and taking into account the collected transportation volume needed it was possible to identify 58 (33+14+7+4) truck per week for outbound synergies (see Table 5). The same procedure can be applied for inbound.

Table 5: Resume of supplier needs for outbound traffic per week in terms of FTL

	Spain	France	Germany	Poland
ColepCCL	16			2
Cort. Amorim	6	3	4	2
Grohe			2	
Karmann Ghia			1	
Simoldes	11	11		
<b>Total</b>	<b>33</b>	<b>14</b>	<b>7</b>	<b>4</b>

## 5 –Train Implementation

Takargo has introduced train transportation in March 2010. It runs 7 trains per week for Ikea Company, using the concept of swap bodies. As a comparison note, for IKEA, 20 swap bodies (based on IKEA needs) are being used in train option in a shared option.

The concept of swap bodies is done at the Spanish/French border at "Irun", located in the north border, or "Portbou", in the south border, for the transfer from the Iberian to European rail system. The proposal is that one train should take around 30 to 36 swap bodies. Capacity is limited due to the capacity of secondary railways that are used to reserve cargo trains allowing faster train to pass by in Portugal. Based on average production values, V-AE project requires 3 to 5 trains in transit per week, therefore around

90 to 150 swaps. This represents around 4320 to 7200 swap bodies transported between Portugal and Germany per year as detailed and explained in Table 6.

Table 6- Train arrival scenarios based on assumption- 1year=48 weeks and 1 train=30 trucks= 30 swap bodies = 15 wagons

	Scenarios	3 trains Week	4 trains Week	5 trains Week
Weekly	Trains	3	4	5
	Power units	3	4	5
	Wagons	45	60	75
	Swap bodies	90	120	150
	Trucks	90	120	150
Yearly	Trains	144	192	240
	Power units	144	192	240
	Wagons	2160	2880	3600
	Swap bodies	4320	5760	7200
	Trucks	4320	5760	7200

## Conclusions

Train option was implemented and in spite of problems of different operation system, rules and rail gauge different sizes in Iberia from the rest of Europe. Also was proved that is possible to use train deliver JIT parts to automobile plants in Iberia with several associated problems (missing train transportation habits and also infrastructure). After a two years testing (2010 and 2011), the start Rail Project was January 2012. Investment prices were supported by Takargo based on a 5-year contract. An estimative indicates that they are required 4 motor wagons; this would mean a minimum investment of 20 million euros. Rough calculations from Takargo are that the total investment would be needed to cover the need of 400 to 600 Swaped bodies, representing 25 Mio Euros. Rough cost of one train is 5 (five) Mio euros (One Power Unit and 14 goods-wagon). This would represent an investment by Takargo of approximately 50 Mio Euros. Taking into account average truck price against train Takargo price represents a potential saving of around 20% of Logistic costs (calculation performed at V-AE taking into account truck versus train costs), when train and supplier synergies were introduced. This means the reduction of the V-AE logistic costs from 7% to 5.6%, a reduction of 1.4% points of total Plant costs. For flexible suppliers enrolled in the project there are also saving because they can pay less than 50% of the real cost, mainly due to the usage of spare capacity in the outbound. This approach reflects a particular case study, therefore findings cannot be generalised (Yin, 2009). Nonetheless the tool is easily adapted to other situations as the solution is flexible.

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# EFFICIENCY IN HAULIER RELATIONSHIPS FROM A SUPPLY CHAIN MANAGEMENT PERSPECTIVE – A MULTIPLE CASE STUDY

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## Abstract

### Purpose of this paper:

Previous literature has outlined the benefits of long-term relationships between carriers and other supply chain members, without addressing the carrier efficiency issues caused by other supply chain members. The focus of this paper is on motor carriers' transport operations with the purpose of examining their efficiency issues and analysing the effects of supply chain management on their operations.

### Design/methodology/approach:

The empirical base used for the analysis comes from exploratory case studies involving six transport operators in Sweden and Switzerland.

### Findings:

The result of this work identifies various efficiency issues motor carriers face in their daily operations, both related to the physical as well as the administrative processes. In addition, it shows that other supply chain members frequently cause issues affecting the carriers' operational efficiency.

### Value:

Previous literature in SCM has emphasized the positive effects of long-term collaboration between various actors, but this paper has examined motor carrier operations from a supply chain perspective and found that despite a long-term relationship and certain process and information integration, disorganized operations of other supply chain members drive motor carrier efficiency issues.

### Research limitations/implications:

This research implies the importance of appropriate supply chain management process design, including the transport operators playing an important role in supply chains.

### Practical implications:

Companies aiming for sustainability, have to consider the efficiency of their contracted motor carriers, in order to avoid unnecessary environmental impact.

## BACKGROUND

The literature on the relationship between haulers and other SC members has generally focused on the *benefits* of long-term relationships. Beier (1989) discusses "the benefits which may result from the continued relationship of transportation haulers... and their clients," and Gentry (1996) discusses efficiency benefits from open communications and information sharing, joint problem solving and continuous improvement, and shared risks and rewards. Fugate et al. (2009) outline successful operational collaboration between shippers and hauliers, but despite these benefits, several general efficiency problems remain and have not been addressed to the same extent (Mason *et al.*, 2007; Sternberg *et al.*, 2014). Though the transport literature provides considerable information on efficiency problems pertaining to the processes within the haulers' scope of control and several studies on strategic collaboration (Hartmann and de Grahl, 2012), empirical studies indicating the problems derived from other supply chain members are sparse (Mason *et al.*, 2007; Sanchez-Rodrigues *et al.*, 2010).

Mason et al. (2007) use a list of seven transport and logistics efficiency problems characteristic of supply chain transportation in their article on vertical and horizontal collaboration in transportation: high inventory carrying costs, unproductive waiting time, high transport costs, lack of critical network mass, empty running miles, long cycle times, and poor on time performance. The causes of these problems include excessive waiting time due to security procedures, slow administration, poor planning or lack of terminal resources (Fugate *et al.*, 2009). Nilsson et al. (2017) found that many companies have very little insight into hauler operations and Sternberg and Harispuru (2017) suggest that a major part of hauler inefficiencies stems from other supply chain members. Consequently, transportation should be managed within the context of the supply chain settings, and therefore it is important to initially establish an understanding of the characteristics of modern SCM. Naim et al. (2006) highlight the literature gap on supply chain collaborations with haulers in general and propose detailed case studies as the way forward to explore the gap; the literature gap was further confirmed by Rodrigues et al. (2008) and Klaas-Wissing and Albers (2010).

Given the low level of efficiency in hauler operations, the increasing transport share of supply chain costs and the lack of literature, research is needed on hauler efficiency that applies a broader perspective than just that of the internal operations of the hauler. *Hence, this paper analyzes how the lack of process and information integration with the haulers' upstream and downstream partners causes negative impacts on hauler efficiency.*

To achieve this aim, multiple in-depth case studies were carried out and the findings analyzed using the SCM literature. In particular, the framework suggested by Cooper et al. (1997) was applied, where SCM consists of three main elements: business processes, network structure, and management. The first two elements are considered the primary operations in transportation in the case studies. The network structure varies but in this study, it is limited in scope because we are only analyzing the hauler and their upstream and downstream partners. This framework was selected, and in particular the element "management components" (p. 6), because it provides a list of ten SCM components that deal with structuring and managing business processes within and between organizations. The framework provides an effective basis from which to analyze the data because it addresses both internal and external processes. By doing so, the SCM problems identified that originate in one member's operations and affect other members' operations, such as transport operators in the SC, can be structured.

## **METHODOLOGY**

The case studies involved six haulers and supply chain members with interfacing processes. Although the sample was not exhaustive of all the possible hauler-supply chain member relationships, it was chosen to reflect diversity along several dimensions, such as supply chain position relative to the focal hauler (i.e., upstream, downstream or both), type of products transported and industry segment (Eisenhardt, 1989). This research is dyadic in nature and in the supply chains where both supply chain members upstream and downstream of the hauler were studied, the focus was still on the dyadic relationship between the hauler and the respective supply chain member (i.e., relationships and processes outside the scope of the hauler were not included). In the selection of cases, a long-term relation (min. 5 years) between the members was a requirement. Data collection from the three cases from previous projects was carried out over extended time periods (2-3 years), with one of the authors physically spending considerable time at both hauler facilities; for a period of 4 months, one author was even employed by a supplier to improve hauler efficiency. As a part of the exploratory approach, open-ended interviews were conducted. The interviewees were encouraged to speak freely about operational efficiency in order to better understand the nature of transport operations and problems that transport companies are dealing with in their daily operations (Ellram, 1996).

The interviews were conducted on-site at the hauler company facilities and included respondents who served different roles in the organizations. High-level senior managers



were the first to be questioned on their views of the companies' operations and to give a description of their upstream and downstream relationships. CEOs were asked to list their customer base in terms of turnover and the organizations to which they delivered. The second phase included in all instances an extensive facility tour, documentation studies and interviews with transport planners. The third phase followed, with driver interviews and a participant observation including author participation in the drivers' assignments for entire days in their trucks while documenting and time measuring the processes in detail minute by minute. From the interfacing SC members, interviewees were selected from the staff interfacing with the hauler, which was primarily terminal managers, forklift drivers and administrators who handled consignment notes. 57 interviewees contributed in total, with 5 to 10 interviewees per case. Interviewees were mainly CEOs, traffic controllers, terminal managers and workers, truck drivers and office clerks.

In Cases A, B, C and F, notes were taken during the interviews and sent back to the respective managers. For time reasons, this procedure of validation was not followed for non-management staff, but for the majority of the interview and observation occasions, two researchers were present, contributing to reliability of the data collection (Yin 2003). The operations manager of Case D and the supplier SCM manager of Case E attended a presentation of the study findings and received an earlier version of this manuscript for validation. This methodology resulted in a very rich data set that made it possible to analyze the transportation activities step-by-step, both administrative as well as the physical ones (Yin, 2003). To analyze how various supply chain members affect hauler efficiency problems, an analytical framework was adapted from the SCM conceptual framework of Cooper et al. (1997).

### **ANALYTICAL FRAMEWORK**

To be able to analyze the complex transport management problems pointed out above, an analytical model that can cover a variety of management problems is required. This drove the quest for a framework that included a list of management components that could be used for data analysis and that covered the various aspects of operations management, and specifically, transportation management. This analytic model needed to address problems on different levels, ranging from general long-term administration problems to day-to-day operations problems. It should include high level organizational and relationships problems of the participants, and be related to process monitoring and planning, which are such important aspects of transport operations. It should also cover information flows and infrastructure problems. The authors, however, were able to identify one framework that included most of the problems pointed out above. This is the SCM framework from Cooper et al. (1997). The conceptual framework emphasizes the interrelated nature of SCM and has three major elements:

Supply Chain Business Processes: The key business processes generating value for the customer.

Supply Chain Network Structure: Outlining the key supply chain members with whom to link processes to.

Supply Chain Management Components: The level of integration and management applied for each process link.

This framework was selected because it provides a list of ten different SCM components that deal with structuring and managing business processes within and between organizations. The framework originally was applicable for traditional product seller-buyer relationships, and did not particularly take into consideration the transport processes. Therefore, it was necessary to change the original SCM framework and adapt it to a transport operation analysis. The change resulted in seven components: two of the originals were eliminated and two were merged into one, in addition to small changes in one existing component. The eliminated ones were the "product structure" because it deals with product design and development and is not applicable, and "management methods" because it deals with corporate philosophy, which is outside the scope of this research. The component "organization structure" was merged with "power and leadership structure" as

the two resulted in very similar problems that overlap to a great extent. Finally, the “product flow facility structure” was changed to “freight flow facility structure” as the original one deals with sourcing, manufacturing, and distribution activities, while this study focused on transportation activities only. The seven adapted SCM components based on Cooper et al. (1997) and used to analyze the efficiency problems of haulers in SC are listed in Table 1.

*Table 1: The seven SCM components of the analytical framework applied in this paper, adapted from Cooper et al. (1997).*

Work structure	The work structure indicates how the firm performs its tasks and activities and describes how work is divided in the studied cases.
Freight flow facility structure	Product flow facility structure in the original framework was changed to “freight flow facility structure.” SC members’ infrastructure such as terminal and loading/unloading equipment, has a large impact on the efficiency of hauler operations (Fugate et al., 2009).
Planning and control	This attribute describes how and by whom the work is planned and controlled.
Information flow and IT structure	The relevant business information exchanged between the organizations and, if applicable, the technology enabling it.
Organization, power and leadership structure	A SC typically has one or two strong leaders that either exercise power or the lack of it. This attribute describes the relationship in the setup in terms of power.
Risk and reward structure	Describes how risks (e.g., costs) and rewards (revenues) are shared between the supply chain members studied.
Culture and attitude	Aspects of culture include how employees are valued and incorporated into the management of the SC. In this paper it refers to the cultures and attitudes perceived by interviewed staff: managers, transport planners, freight administrators and drivers (Mello and Hunt, 2009).

## EMPIRICAL ANALYSIS

This section presents the case studies and the results of the analysis. A general description of each case is include.

### Case A

Case A is a supply chain of general cargo (mainly palletized construction material) in Switzerland. Hauler A’s largest customer (Supplier A) supplies construction sites and construction shops throughout Switzerland.

Destination information for deliveries at construction sites usually contains just the address or a rough description. At unloading drivers stop, walk around and try to find the responsible manager at the construction site or drive around to find a location to unload. Frequently, the supplier sets deadlines for deliveries at construction sites to, for example, 9:00 or 10:00 a.m., which means the drivers have to adapt their routes to match these deadlines. A change in route typically mean that the work day is extended. As a result, an average work week for drivers is 53 hours (all hours over 45 have to be paid out as money or compensated with paid leave). Hauler A also faces driver turnover of 30% each year. The supplier is aware of the problems related to these constraints, but being in a position of power, persists in adding them, which has resulted in decreased efficiency and driver stress. The drivers were observed to be extremely distressed when the routes they had planned at home (they receive the amount of goods and destinations the night before) were incorrect, since deadlines were scribbled on the consignment notes.



After a transport order has been completed, five members of the administrative staff (Hauler A has 7 administrative employees including the CEO) spend some 20-60% of their time calculating and checking invoices based on returned and signed consignment notes. Even though the consignment notes contain pre-calculated freight rates, the supplier and Hauler A have an agreement on special freight rates, and thus all rates have to be recalculated. One of the staff members stated: "This is our biggest customer ... I generally spend 3-4 hours a day with the consignment notes of their goods and when I'm done I give it to our accountant, who spends another 2-3 hours a day checking what I have done." Having 7 administrative employees for 40 trucks is a lot compared to other haulers. Salary records and several days of observations indicate that the extra invoicing work that result from the work structure agreed upon between Hauler A and Supplier A costs a minimum of €15,000 per year – but the actual cost may reach as high as €30,000 per year. Unloading equipment was absent at several unloading locations. This was a general problem for haulers who delivered to small construction sites.

### **Case B**

Case B is about general cargo for manufacturing, retailing, etc. The case focuses on the relationship between Hauler B, the LSP B (one of the world's largest) and the customers/receivers of LSP B. Whenever the specifications of a consignment are believed to be incorrect, Hauler B measures and updates the freight specifications. Later, the invoice is drawn up according to the updated specifications for LSP B who invoices the final customers. If the customers disagree with the invoice, they contact LSP B who directs them to Hauler B.

When Hauler B reports incorrect addresses to LSP B, LSP B requests that their customer rectify the information, but due to the incentive structure in use, the cost for the extra work resulting from the erroneous information is carried by Hauler. A similar effect applies for erroneous packing of shipments. In LSP B's general conditions, the customer is responsible for damages to insufficiently packaged goods, but the drivers usually improve the packing to avoid the time consuming process of reporting goods damages, which during busy terminal hours can take up to 20 min. When Hauler B invoices LSP B, they have to state the name of the staff member signing the consignment note. When the name is illegible, additional administrative work is required. One of the drivers stated: "It's really silly to ask some receivers I meet daily for a signature." This exemplifies how a long relation between staff of haulers and interfacing partners can actually cause an efficiency problem (additional work) by the Hauler's administrator.

### **Case C**

Case C is about general cargo mainly destined for retail. This case involves a large intermodal hauler (Hauler C, 3000 employees, 30 at the location studied) and a port. Hauler C loads containers in the port and transports them to the proprietary terminal where the shipments are broken up into small assignments and consolidated with other freight. When a Hauler C driver arrives at the port, he has to check in at the port administration (often waiting in line) and when the check-in is completed, await a time slot for loading or unloading. The check-in procedure takes between 5 and 15 minutes and the waiting between 10 minutes and 3 hours. Hauler C does not collect any statistics on the total waiting time, but the variable cost (driver + truck) is calculated at €45 per hour. After the truck has been loaded with a container, the driver drives back to the terminal and waits to get unloaded (unloading containers in the port takes the same amount of time). The container is unloaded and the terminal staff divide the consolidated freight into new shipments for the receivers. The shipments are loaded into trucks that deliver them to the final customer. Since no IT integration exists between Hauler C and its shippers and receivers, and due to the variance in transport times of trips to and from the port, each driver always has to go back to the terminal to retrieve paper documents with the next assignment. At customer sites, waiting times of 1 to 15 minutes generally apply before the unloading can start.

### **Case D**

Case D is a transport setup including general cargo (mainly construction material, food and tires) in Switzerland. Hauler D's largest customer (15% of the turnover) supplies kitchen equipment (Supplier D) to construction sites and warehouses throughout Switzerland and southern Germany. Unloading of kitchen equipment frequently takes a long time since unloading locations are not prepared which means that the drivers have to move items from the terminal platform to make space for the items they need to unload. Supplier D has for the past years continuously negotiated the transport rates in order to lower them. The operations manager states: "We are already losing so much money on many of our assignments and we make it worse for ourselves by accepting those rate cuts." The large volume from the largest customer puts it in a position of power over Hauler D, a power exerted on the reward structure and on the work structure. A customer providing an erroneous address fee is billed 20, 30 or 50 CHF (50CHF=57 USD). Note: Outside the relationship between Hauler D and Supplier D, Hauler D has some smaller customers who frequently order transport services over the phone. Some information is often distorted, such as when the first author followed a driver on a 300 km trip (one-way). The customer said they ordered a truck with a crane and the driver's truck did not have one. As a result, 600 km were driven without revenue. Small- and medium-sized customers cause efficiency problems through information sharing over the phone, frequently resulting in errors.

### **Case E**

For the purpose of the case study, the focus was set on transports from Supplier E to its customers in Norway. The fill rate of Hauler E is rather low, approximately 40% depending on season. Supplier E pays Hauler E per trip, independent of fill rate. For the Norwegian market only (a small market with a few food plants), the problems in the planning process yearly represent 50 out of 260 transports being loaded with 10 to 25 tons. For the typical trip to Norway, the haulers charged €1500 and for this market, the total cost of this inefficiency is between €20,000 and €40,000 yearly. 3% of Supplier E's transports are carried out by another hauler. The transport manager of Supplier E motivates it as follows: "We have a long-term collaboration with Hauler E, but it is important that they know they should continue to improve." Open communication between Supplier E's logistics department and the staff of Hauler E was evident and several family ties exist between the planning departments of the companies. Supplier E is clearly in a position of power, yet did not take advantage of this in the way that they could have, as was observed in other cases. There were indications that the culture and attitude between the firms was the main reason for this.

### **Case F**

Case F is a supply chain of palletized automotive components for two major vehicle manufacturers in west Sweden. Hauler F is a small hauler (10 Trucks, 15 employees), mainly operating milk rounds, stopping at various suppliers to pick up components for the automotive industry and to deliver returnable packaging material. According to the legal agreements, the automotive component suppliers are responsible for loading the trucks of Hauler F, but according to drivers and as confirmed by several participant observation trips, this is rarely the case. The suppliers are small companies and the drivers and the staff members know each other well. If the supplier has two forklifts, the driver will use one and collaborate with the staff loading and unloading to speed up the process. At one of the supplier's sites, the driver simply opens the doors of the facility, starts the forklift and does the whole process himself. When LSP F is unable to unload/load in the allocated time slot, the truck drivers are requested to stay in the terminal and thus exceed their allocated time (this is paid for by LSP F). Hauler F invoiced an average of 15 hours waiting per truck per week during 2007-2008. Every hour is charged €45 by Hauler F and with two trucks running milk rounds for LSP F, that signifies an additional €67,500 in revenue. According to the CEO, these excessive waiting hours, despite the extra reimbursement from LSP F, are his biggest problem since the drivers are very unhappy about, coming home at 11 p.m. on Friday night. LSP F, despite being very open about the problems they face, did not give their consent to the authors to publish the total amount of extra waiting time paid for.

While the relationship between the consignees and Hauler F illustrate a smooth flow and good cooperation (similar to Case E, but as in Case F without any contractual links between the firms), the operations interfacing LSP F differ. The operations manager of the terminal of LSP F states: "We have big problems in our terminal planning and we are short on forklift drivers. We need more young guys with a wife, two kids, a house mortgage and the desire to work overtime." Despite LSP F assuming responsibility (i.e., a cost structure where the haulers are compensated for waiting time outside time windows), it has not caused LSP F to improve. From the interviews, the authors concluded that LSP F did not solve their efficiency problems due to lack of interest and commitment to change. This lack distorts the planning of Hauler F.

## **CONCLUDING DISCUSSION**

Efficiency problems in hauler operations have thus been the theme of this research. All operational inefficiencies increase the total supply chain costs and inefficiencies in hauler operations are no exception. At the end of the day, this supply chain inefficiency results in higher product price, paid by the final consumer, and makes the specific supply chain less competitive compared to other chains with lower total costs.

The results of this research stretch into the area of discussing how some of these inefficiencies can be avoided. By analyzing the data using the suggested SCM model, problems related to seven types of management components in SCM have been identified. The results show that lack of interaction with the haulers' upstream and downstream partners negatively affects the haulers' overall efficiency and in turn, that of the entire SC. To make the analysis more rigorous, an analytical framework was adapted from the SCM conceptual framework of Cooper et al. (1997). This approach established a comprehensive analysis of tasks carried out by the drivers and made it possible to investigate efficiency problems throughout the daily operations of their transportation activities. The adapted framework has proved to be a theoretical contribution because it brings forth a structured process for analyzing results of studies in the hauler industry and can be used to prepare research design and identify units of analysis in future studies.

The results of the analysis clearly indicate that major hauler efficiency problems exist in all of the seven suggested SCM components. Comparable efficiency problems are partially addressed in previous literature dealing with aspects of transportation problems in SCM, such as work structure (Mason *et al.*, 2007), freight flow facility structure (Fugate *et al.*, 2009), planning and control (Mason *et al.*, 2007), information flow and IT structure, power and leadership structure (Fugate *et al.*, 2009), risk and reward structure and culture and attitude (Mello and Hunt, 2009). Previous research has highlighted the benefits of improved collaboration (Beier, 1989; Gentry, 1996), but without addressing how collaboration can tackle these frequently reported efficiency problems.

Important managerial problems have been identified as the data reveals extensive time spent on administrative work due to redundant processes, especially during verification activities. This goes for both terminal activities as well as during visits to customers. In addition to inefficiency during loading and unloading, some problems were identified related to planning and control where one SC member caused constraints that affected the operation of the other partners. Ineffective information flow and lack of coordinated IT infrastructure tends to be the root of many inefficiency problems that cause more time to be spent on many activities and in turn, lower the utilization of both vehicles and drivers. The information flow problems are often related to technical problems but also organizational, where power and leadership structures do not benefit the haulers because many of them are relatively small compared to their partners in the supply chain. The identified inefficiencies show how lack of interaction with the haulers' upstream and downstream partners cause negative impacts on hauler efficiency. The effects that include low fill rate, extensive waiting, unnecessary driving, and slow handling in terminals need to be eliminated to gain the efficiency improvements required to improve the supply chain competitiveness.

This paper has examined hauler operations from a supply chain perspective and found that despite a long-term relationship and certain process and information integration, disorganized operations of other supply chain members drive hauler efficiency problems. Given the neglected role of transportation in previous supply chain management literature, the impact of transportation on, for example, logistics costs, customer service and the environment should gain increased attention in the future and haulers should be included to a higher extent in future supply chain management studies.

The theoretical contribution of this research is based on an adapted framework using seven management components for data analysis that cover various aspects of transportation management. This analytic model addresses transport management problems on the short-term operational level as well as the long-term strategic level.

The managerial contribution of this research includes problems that need to be addressed to increase the efficiency of transport operations. The major ones are how roles and responsibilities are divided between partners, the importance of information flow and collaboration in planning activities as well as more effective risk and reward structure.

This research is based on six cases that show inefficiencies in hauler operations in Sweden, Norway and Switzerland. When selecting cases, a long-term relation between the members studied was a requirement. In addition, the selection was made to reflect diversity along several dimensions such as supply chain position, type of products transported and industry segment. The sample is not exhaustive of all the possible hauler-supply chain member relationships and despite the diversity, the results are limited to similar type of operations.

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## **Session 9: Cold Chain Management**

# CLIMATE CONDITIONS AND TRANSPORTATION: AN HIDDEN CONNECTION IN COLD CHAIN MANAGEMENT

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## ABSTRACT

### PURPOSE OF THIS PAPER:

This paper presents an overview of the extant recent literature on the design and management of transport systems for perishable goods, in order to question and discuss the hidden interdependencies between the distribution of temperature-sensitive products (e.g., food, pharmaceutical) and the weather conditions or environmental stresses experienced during this phase.

### DESIGN/METHODOLOGY/APPROACH:

We overviewed the state-of-art of the literature dealing with the planning and scheduling of transport activities for temperature-sensitive products in order to highlight the hidden constraints and impacts resulting by the weather and environmental conditions experienced during the shipment. We also provide a support-decision abacus that classifies a shipment according to a set of existing constraints and drivers (e.g., based on the geographic area, the extant network infrastructures, the characteristics of the products), and identifies potential criticalities, risks as well as optimization opportunities.

### FINDINGS:

We stated the lack of supporting models and quantitative methodologies that involve the weather conditions in the planning and scheduling of loading and distribution operations for perishable and temperature-sensitive products.

### VALUE:

We study and introduce an original not yet handled problem in the planning of transport operations and design a conceptual framework to aid its modelisation.

### PRACTICAL IMPLICATIONS:

We provide a support-decision abacus that allows the analysis of the potential risks associated to a shipment and suggests how to prevent them.

## 1. INTRODUCTION

The distribution of perishable food products require a strict control of the environmental conditions to maintain an adequate level of freshness, such as food, pharmaceutical or flowers. For these products, customer satisfaction is closely related to the level of freshness of the product at the grocery ([Wang, 2016](#)). Freshness is influenced by time and environmental conditions, such as temperature or humidity. For food, an inadequate preservation results in physiological changes, alterations in texture, flavour and taste that are undesirable for customers, determine losses or waste, and can further represent a threat to consumers' health. To avoid wastes, the perishable products must be stored at their optimal storage conditions throughout the chain. Currently, up to one third of all produced food is lost or wasted before it reaches the consumers, implying enormous costs, energy consumption and a moral problem (Kefalidou, 2016).

The climate conditions non-linearly influence the quality decay of perishable products. The Arrhenius equation describe a non-linear connection between temperature and the reaction rate that induces the shelf-life decay.

This exponential relation between climate conditions and the reaction rate of quality decay pushed the practitioners to adopting new solutions to guarantee a strict control of environmental conditions inside the storage room and transportation systems. In the past decades, many efforts have been made to guarantee an increasing level of service to consumers ([James, 2006](#), [Smith, 1990](#)). The main strategy adopted to pursuit the enhancement of the quality of product lies on the improvement of the inside environmental conditions in storage room and transportation systems. As a consequence, the adoption of new technologies progressively contribute to reduce the food losses due to early decay. Nevertheless, the operative and capital costs associated to these technologies, smooth their adoption in less developed countries ([Kefalidou, 2016](#)). As example, the waste rate of fruit in less Developed Countries is twice than in the European Union (FAO Food Balance Sheets) (see Table 1).

The improvement of the conservation conditions can also be pursued by using better packaging ([Defraeye et al., 2015](#)), or better materials for storage rooms and vehicles ([Adekomaya et al., 2016](#)) as well as better technologies for the refrigeration of perishable products ([Hoang et al., 2016](#)). In most areas of the world, the adoption of this technology can be not feasible (i.e., because of the lack of developed energy grids) or not affordable. Refrigeration indeed decelerate the chemical and biological process of degradation extending the shelf life of the products (Stoecker, 1998). However, is clearly energy intensive and consume about the 15% of the overall electricity consumption worldwide ([Coulomb, 2008](#)).

<b>Fruits - Excluding Wine</b>	China	European Union	India	Less Developed Countries
1984-1988	7.38%	6.09%	12.63%	11.97%
1989-1993	6.83%	6.20%	13.00%	11.13%
1994-1998	7.22%	6.39%	13.29%	9.53%
1999-2003	6.91%	6.61%	13.54%	9.53%
2004-2008	7.34%	6.45%	13.99%	9.92%
2009-2013	8.57%	5.84%	14.15%	9.45%

Table 1. Waste rate [%] for fruits (FAO, 2017).

Consequently in less developed or developing countries, these lacks couple with higher rates of losses along the supply chain. In China, as example, the cold chain adoption rate is 5% for fruit and vegetables, 15% for meat and 23% for, while the food losses for these categories are respectively 20-30%, 12% and 15% ([Wang, 2013](#)).

Climate conditions are typically handled as unpredictable. Hence, protective approaches are adopted as insulating covers or containers that protect the load from stresses during storage or transport..

Other approaches might use the forecast of the weather conditions to prevent from environmental stresses, thereby exploring the hidden connection between climate and transport of perishable products. Weather forecasts can be indeed considered to implement preventive approaches aimed to the proper scheduling of transport operations. As example, the deliveries of perishable products could be scheduled to meet the less stressing environmental conditions over the day (i.e., early in the morning or during the night) or the week (e.g., rainy days). This smart approach would result in less consumption of energy for refrigeration and at least less need for better insulation. In those areas worldwide characterized by elevated values of temperature and humidity, such approaches might reduce significantly the costs of the supply chain and further the GHGs emissions due to energy production. Although a preventive approach might avoid the rapid decay of perishable products without increasing costs or energy consumption, we have no evidence of similar approaches discussed in the extant scientific literature.

The raising attention to reducing energy consume in food supply chains, the awareness of the impacts of climate change on both environment and society, the need to comply with higher standards of quality and to meet consumers' expectations, should indeed justify the



development of new decision-support quantitative approaches. These should explore the hidden connection between climate conditions and transport activities via mathematical modelling for leading the decisions on how to plan and schedule the distribution of perishable products. A comprehensive model should hence incorporate the interactions between the traditional issues of food supply chain management (i.e., on-time deliveries, shelf-life decay, packaging) and the climate conditions. As far as such a model is still lacking to the best of our knowledge, we analysed the extant literature on quantitative food supply chain management methods that cover different branches/issues of this field. The conducted survey depicts a progressive interaction between these issues. These interaction and connection is thereby promising for the formulation of innovative models toward the aforementioned goal. Since the formulation of the model is not the aim of this paper, in the following we conclude this exploratory analysis by assessing the scenarios that in practice could obtain benefits from the adoption of such models. The remainder of the paper is arranged as follows.

In Section 2, we carried out an in-depth review of the literature. In Section 3, we illustrate a support-decision abacus that classify different perishable distribution scenarios. In Section 4, we discuss the result of our exploratory study and announce further research developments.

## 2. LITERATURE REVIEW

We overviewed the state-of-art of the scientific literature on the planning and scheduling of transport activities for temperature-sensitive products. This survey sought to highlight the hidden impacts associated to the weather and environmental conditions experienced during the transport activities. Although we have no evidence of quantitative climate-driven approaches that involve weather consideration in planning and scheduling of food distribution, we classify some literature branches whose interdependences justify the necessity of such innovative models.

These branches are:

- GHGs emissions and sustainability. These include the literature about the environmental impacts due to energy consumption in the cold chain;
- Shelf life. This area deals with the modelling of the quality decay and the shelf life of perishable products;
- Temperature and weather. Specifically, the impacts of weather conditions on the temperature control systems inside the trucks and the distribution containers;
- Transportation. This includes the papers which study the choice of transport mode to adopt for perishable products deliveries;
- Packaging. The focus on this area is the interaction between packaging and perishable products' conservation.

-

These five branches are strictly interconnected because they all contribute to determining costs, carbon emissions, and quality decay throughout the supply chain. In between these areas we find some quantitative models that indirectly involve the influence of weather on transportation. This is incorporated through input parameters but does not affect directly the decision process. Thus, the scheduling of deliveries is planned without climate considerations, whose impacts on costs are even neglected in the objective functions.

The integration of these branches into a unique optimization model has no examples in the studied literature. The increased interest in reducing the energy consumption, tackling the climate change, and the cost-effectiveness of the supply chain are pushing together fields which are apparently not mutually connected. Fig. 2 summarizes five different fields of the literature and shows how this paper is positioned in the black area in between the intersection of these.

[Smale \(2006\)](#) proposed a survey of model based on the computer fluid dynamic (CFD) focused on the distribution of the room temperature in refrigeration systems. By assuming that external temperature is neither controllable nor predictable, they propose a model to assess the homogeneity of the room temperature in a refrigerated system. [Zwierzycki et al. \(2011\)](#) provided a software for evaluating temperature stabilization of cold chain transport based on a CFD approach. This software enables to evaluate the impact of external temperature at the time of delivery on the bases of the adopted on vehicle and the load utilization.

[Vanek and Sun \(2008\)](#) proposed a model to explore the trade-off between energy consumption by the refrigeration system and the shelf life decay. This model link together the sustainability of the cold chain and the shelf life of perishable products but temperature or external weather

conditions are not incorporated in the mathematical formulation. [Chen et al. \(2009\)](#) provided a production scheduling and vehicle routing problem with time windows for perishable goods (PS-VRPTW-P). Their model provides a framework for the optimisation of production scheduling and for the deliveries to the customers subjected to strong time-windows limitation. [Coelho and Laporte \(2010\)](#) proposed a model that integrates inventory management and vehicle routing issues for perishable products. The resulting perishable inventory-routing problem (PIRP) considers the impact of time on inventory holding costs and revenue, due to the quality degradation of perishable items, and inventory management policies. [Amorim and Almada-Lobo \(2014\)](#) formulated a multi-objective vehicle routing problem subjected to time window constraints (VRPTW). This model minimizes the total routing costs while maximizes the freshness of the products. In these four models, quality decay is affected only by time. Perishability indeed is treated through the product expiration date, but the other key factors influencing the perishability, as temperature and humidity, are neglected in the formulation. [Zanoni and Zavanella \(2012\)](#) included directly the effect of temperature both on the food quality degradation, on the energy requirements and the sustainability of the cold chain. This model, nevertheless, does not focus on transportation, but considers the contributions for the storage at the different stages of the cold chain. [Hsu et al. \(2007\)](#) proposed a stochastic vehicle routing problem with time-windows (SVRPTW) that considers different deterioration rate depending on temperature. The resulting model minimizes the total cost for inventory and transportations by considering stochastic travel time. [Gwanpua et al. \(2015\)](#) designed a tool to optimize the trade-off between food quality, calculated via kinetic models, energy consumption and global warming impact of the cold chains. [Jedermann et al. \(2014\)](#) highlighted the importance of reducing perishable products losses. Although they did not propose any mathematical model or quantitative approach to address perishability, they provided some insights for the proper correct management of cold chains. They proposed an approach for the determination of shelf life based on the Arrhenius equation that considers the effect of temperature on the reaction rate. Their paper also pointed out the need for accurate and smart packaging or proper container solutions to minimize food losses. [Adekomaya et al. \(2016\)](#) proposed a redesign of food transportation systems to reduce the energy consumption and improve sustainability of food supply chains. This paper focused on alternatives energy sources to fossil fuel in order to reduce the global impact of food supply chains. [Defraeye et al. \(2015\)](#) focused on packaging, introducing the need for integrated key performance indicators (KPIs) able to incorporate both an costs and energy aspects. The proposed approach suggest how the proper ventilation of climate controlled rooms can support the maximization of the product shelf life.

	Mathematical model	Emissions and sustainability	Shelf life	Temperature and weather	Transportations	Packaging
Smale (2006)	x	✓	x	✓	x	x
Zwierzycki et al. (2011)	x	✓	x	✓	✓	x
Vanek, Sun (2008)	✓	✓	✓	x	x	x
Chen et al. (2009)	✓	x	✓	x	x	x
Coelho, Laporte (2010)	✓	x	✓	x	x	x
Amorim, Almada-Lobo (2014)	✓	x	✓	x	x	x
Zanoni, Zavanella (2012)	✓	✓	✓	✓	x	x
Hsu et al. (2007)	✓	✓	✓	✓	x	x
Gwanpua et al. (2015)	✓	✓	✓	✓	x	x
Jedermann et al. (2014)	x	x	✓	✓	✓	✓
Adekomaya et al. (2016)	x	✓	x	x	✓	x
Defraeye et al. (2015)	✓	x	✓	x	x	✓

Table 2. Classification of the reviewed papers.

### 3. A SUPPORT-DECISION ABACUS FOR COLD CHAIN OPTIMIZATION MODELLING

The aforementioned models propose solutions for maintaining perishable products at the best conditions when environmental conditions vary from the desired set-point. These solutions arise from the tight, implicit connections between weather conditions and cold transportation.

When the connections between weather conditions and the transport of perishable products are assessed and incorporated into decision-support models are optimal scenarios can be pursued. Transport and distribution activities could indeed be rescheduled according to external weather conditions in order to exploit the most favourable time-windows for the deliveries. Perishable products that need to be stored at low temperatures, as example, could be shipped early in the morning or during the night. This approach would minimize the energy consumption, the need for capital-intensive infrastructure or expensive packaging and would also improve the sustainability of cold chains.

The proposed approach, however, is not effective for all the food supply chains. The combination of optimal storage conditions for the products, seasonality, geographic area and infrastructure availability bounds the feasibility and the convenience of its application. In order to show the most suitable scenarios for its adoption, we provide a support-decision abacus that classifies a cold chain according to a set of characteristics, extant constraints and drivers (e.g., geographic area, network infrastructure and product's features).

This abacus should aid identifying how and where the climate-driven planning of the perishables deliveries and distribution could lead to significant and not negligible economic and environmental savings. The feasibility and the profitability of climate-driven planning depends on the weaknesses and risks bared by the observed supply chain. We propose two classes of levers/parameters to assess and characterized the supply chains. These are:

- Geographical-based constraints;
- Product-based constraints.

The geographical-based constraints include those aspects that deal with the geography and the localization of the supply chain. The geography is the area where the supply chain operations (i.e., packaging, storage, distribution) take place. In Figure 1, we illustrate some samples of the geographical parameters that can be used to evaluate a supply chain. We define an approach based on the Boolean algebra to cluster and classify the sets of geographical areas and assess the feasibility and profitability of climate-driven planning of cold chain operations. The detailed list of the involved parameters is as follows:

- Access to electricity. Let  $AE$  be the countries with high access to electricity and  $\overline{AE}$  be the countries with low access to electricity;
- Energy imports net. Let  $EI$  be the countries with high energy imports net value and  $\overline{EI}$  be the countries with low energy imports net value;
- Agricultural raw materials exports. Let  $AME$  be the countries with high agricultural raw materials exports value and  $\overline{AME}$  be the countries with low agricultural raw materials exports value;
- Agricultural raw materials imports. Let  $AMI$  be the countries with high agricultural raw materials imports value and  $\overline{AMI}$  be the countries with low agricultural raw materials imports value;
- Temperature. Let  $ET$  be the countries with extreme temperature values, both very high values or very low values, and  $\overline{ET}$  be the countries without extreme temperature values;
- Total greenhouse gas emissions. Let  $GHG$  be the countries with high greenhouse gas emissions values and  $\overline{GHG}$  be the countries with low greenhouse gas emissions values;

Data for these parameters were found on data sheet of the World Bank websites (World Bank, 2017).

Using the union and intersection operators between the sets, we classify the countries according to these parameters to provide a taxonomy of the geographic areas that could count or not significant savings by applying the aforementioned climate-driven planning to the cold-chain distribution.

As example, the presence of extreme climate conditions, the poor availability of energy its high costs (i.e., perhaps due to energy import), the high flow of long-ray container shipment (i.e., connected to the import/export balance of agro-food products) as well as high GHGs emissions due to transport make a geographic area potentially interested to adopting cold-chain distribution management approaches that embed weather considerations. The intersection of these sets highlight and point out such areas.

$ET \cap (\overline{AE} \cup EI) \cap (AME \cup AMI) \cap GHG$  = climate-based solutions;

$ET \cap (AE \cup \overline{EI}) \cap (\overline{AME} \cup \overline{AMI}) \cap \overline{GHG}$  = refrigeration-based solutions;

$\overline{ET} \cap (\overline{AE} \cup EI) \cap (\overline{AME} \cup \overline{AMI}) \cap \overline{GHG}$  = packaging-based solutions;

$\overline{ET} \cap (AE \cup \overline{EI}) \cap (AME \cup AMI) \cap GHG$  = container-based solutions;

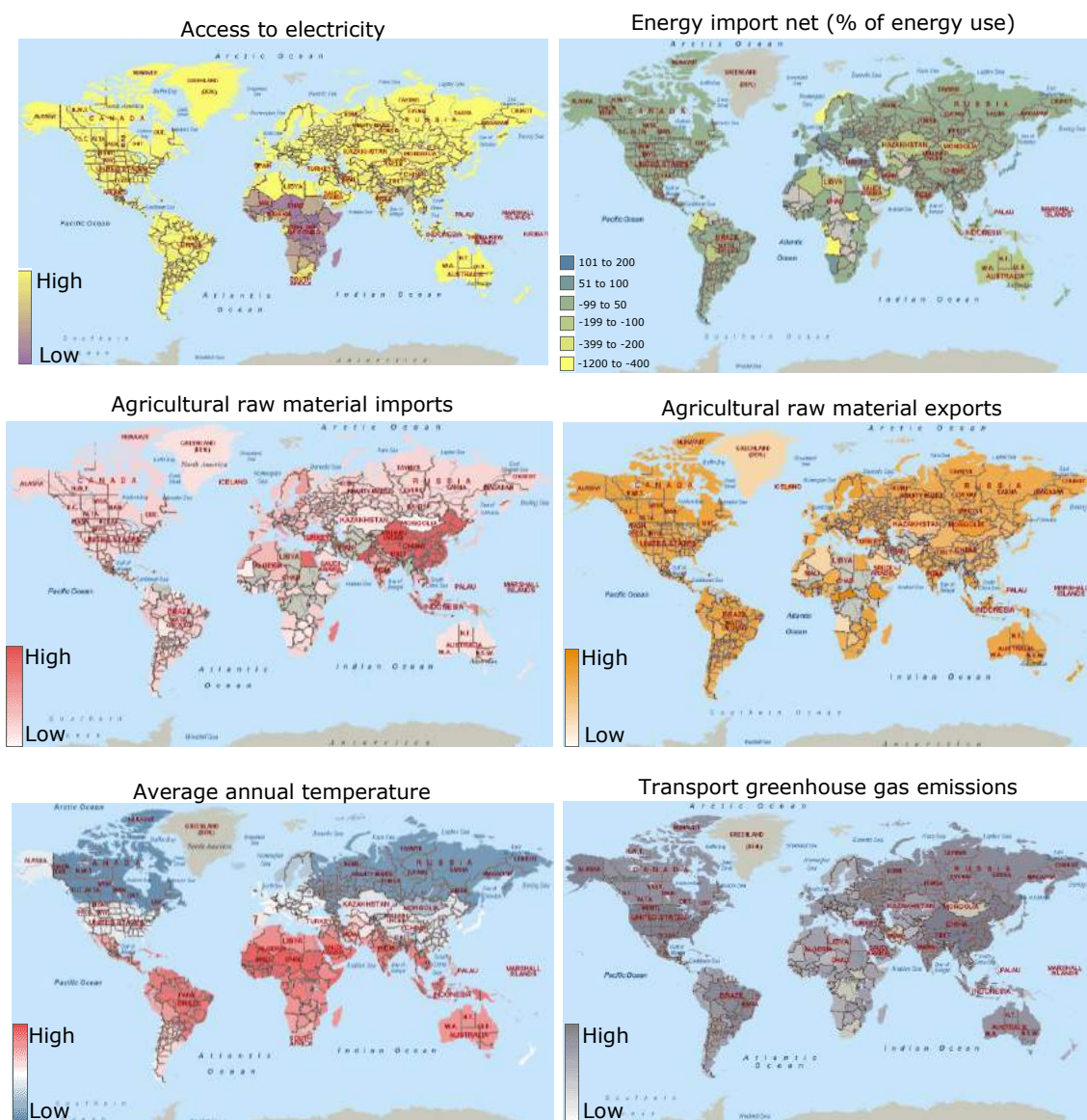


Fig. 1. Geographical-based parameters.

In Table 3, we summarize the suggested strategies for the optimization of the transportations of perishable products in accordance with the given geographical levers and constraints. The recommendations resulting from the geographical-based constraints are integrated with other levers affected by products characteristics. Product-based constraints involve properties of the specific perishable product and variety (e.g., seasonality, shelf-life, optimal conservation temperature and humidity, growing areas).

	Climate-based	Refrigeration-based	Packaging-based	Container-based
Extreme temperatures	yes	yes	no	no
Infrastructure availability	low	high	low	low
Transportation distance	high	low	low	high
Greenhouse gas emissions	high	high	low	high

Table 3. Summary of the proposed solutions.

Product	Ideal temperature [°C]	Ideal relative humidity [%]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
mango	10-14	85-90												
strawberry	0	90-95												
radicchio	0	90-95												
persimmon	0	90-95												
cabbage	0	90-95												

Table 4. Example of product characteristics for agricultural products.

Table 4 showcases an example of product-based constraints to be considered for the proper assessment of the cold-chain weaknesses, opportunities and risks.

By considering simultaneously these two classes of levers/constraints, the feasibility and profitability of climate-driven planning approaches in cold chain can be quickly assessed. As example, a temperature range could be considered extreme or not depending on the optimal storage conditions of a given product. Further, a region with an annual average temperature which is critical for a product could record less stressing temperatures during the season the product grows and is distributed.

#### 4. DISCUSSION AND CONCLUSIONS

The aim of this paper is to highlight the hidden connections between weather conditions and transportation toward the sustainable design and management of cold chains. We present a review of the recent literature on the field, that highlights the lack of mathematical models or decision-support quantitative approaches that involve weather considerations. The feasibility and profitability of such innovative approaches, however, varies according to two main class of levers: geographical-based and product-based.

We illustrate a support-decision abacus that aid the classification of a cold-chain based on geographical-oriented and product-oriented levers, and assess the feasibility and profitability of climate-driven management strategies instead of packaging-driven, rather than infrastructure or technology-driven ones.

The illustrated support-decision is however just the result of a exploratory analysis of this field of research which seems to be neglected by the current research directions. It needs to be improved by integrating other levers and parameters, or by incorporating it into a tool or a GIS system. Further development of this research will undoubtedly focus on the formulation of mathematical models aimed to optimize cold-chain distribution operations involving weather conditions.

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# **SURFACE TEMPERATURE REQUIREMENTS OF FROZEN AND CHILLED FOOD RECEIVING FOR COLD CHAIN LOGISTICS MANAGEMENT**

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## **Abstract**

**Introduction:** The management of food cold chains is receiving more and more attention, both in practice and in the scientific literature. Previous studies revealed that food temperatures in the cold chains were exceeding the required temperatures even more than 50%. The condition is common in Taiwan, but we do not know how they measuring temperatures or only recording the monitors.

**Purpose:** This study aims to suggest appropriate surface temperatures for chilled and frozen foods respectively considering food safety, cold chain efficiency and sustainability. Apart from this, we hope the method can be referred by authorities in Taiwan.

**Design:** 8 kinds of ice cream products and 14 kinds of chilled beverages are measured by digital temperature recorder. Surface and central temperatures were measured by probes, surface temperature are measured by infrared thermometer. Overall data were analyzed through cluster analysis.

**Findings:** There was a high correlation between surface and central temperature. For frozen, correlation is between 0.663-0.985, for chilled one, the correlation is between 0.956-0.999. The correlation was highly associated with weigh according to the clustering group. Therefore, we proposed the surface temperature could be set as 8°C and -8°C for chilled beverage and frozen ice cream products respectively when receiving these products.

**Value:** The method and data may be employed by food safety authorities in Taiwan to develop new regulation.

## **1. Introduction**

Recently, the domestic logistics industry encountered some difficulties in ensuring the safety and quality of food because inappropriate control of temperature. Previous studies revealed that food temperatures in the cold chains were exceeding the required temperatures even more than fifty percent (Zubeldia *et al.*, 2016; Lundén *et al.*, 2014; Morelli *et al.*, 2012; Tingman *et al.*, 2010). This condition is commonly occurred, therefore, strengthening the capacity of logistics industry to control temperature is needed in Taiwan.

According to the draft Code of Good Hygienic Practices for Food Logistics in the "Low Temperature Logistics Health Guidance Program" in 2014, the surface temperature of frozen and chilled food should not be higher than  $-12^{\circ}\text{C}$  and  $10^{\circ}\text{C}$  (TFDA, 2014). Taking into account that the logistics industry can only confirm the surface temperature of products in their service, however, the central product temperature may be different. Therefore, a fully understanding of this correlation is necessary to ensure the temperature of the product can preserve the quality and safety of the particular food. In this study, the surface and central product temperature in ice products and beverages were recorded by using a temperature recorder, aimed to suggest appropriate surface temperatures for chilled and frozen foods respectively considering food safety, cold chain efficiency and sustainability. Apart from this, we hope the method can be referred by authorities in Taiwan.

## **2. Materials and methods**

### **2.1. Sample collection**

In this experiment, eight different kinds of frozen ice cream and fourteen different type of chilled beverages are purchased from supermarkets. The packaging materials of ice cream are mainly plastic and paper and the sample weigh are between 74–109 grams (Table 1). The packaging materials of beverages are plastic, glass, tetra PAK, carton and aluminum can. The chilled beverages samples weight are between 300–600 grams (Table 2).

### **2.2. Experimental Procedure**

Real temperature profile was recorded by using a digital temperature recorder probe (TR-52i, Japan, Tai Ling Co., Ltd.) in the cold storage at the logistic service provider. Also, using infrared thermometer (TM-969, Lutron electronic enterprise CO., LTD.) measured



surface temperature of the chilled food to compare the actual situation. Frozen and chilled samples are measured at constant temperature, separately. To mimic the behavior in logistic industry, the frozen samples are stored in the cold storage room under -18°C for 3 hours and below 7°C for 1 hour and tested in triplicate. Similarly, the chilled samples are stored in the cold room under 7°C for 3 hours and then 15°C for 1 hour.

### 2.3. Center/surface temperature measurement

The sample temperature profile was recorded at the center, surface and environment. In order to measure the sample center temperature, frozen and chilled samples are drilled with an electric drill and then, a connected wire with the digital recorder was inserted into the sample center. The other recorders were used to record the surface and environment temperature.

Sample No.	Sample	Packaging materials	Thickness (mm)	Weight (g)	Milk fat(%)
(A)	snowy pie	plastic	68.91	109.5	14
(B)	sweet cone	paper box	58.44	74±4.5	14
(C)	strawberry flavors	cover: plastic	69.52	81	23
		cup body: paper			
(D)	chocolate flavors	cover: plastic	69.52	81	33
		cup body: paper			
(E)	Hawaiian flavors	cover: plastic	69.52	81	56
		cup body: paper			
(F)	milk flavor	plastic	74.12	95	14
(G)	red bean paste	plastic	46.23	87.5	5
(H)	chocolate flavors	cover: plastic	96.46	392	38
		cup body: paper			

Table 1 The thickness, weight, and milk fat content of frozen.

### 2.4 Data analysis

The obtained data was analyzed using the SPSS software (IBM SPSS Statistics 20) for hierarchical clustering and correlation. The hierarchical clustering was used to classify the frozen sample basic on milk fat, thickness of the product, weight, and each time point of surface and center temperature. The chilled sample also were classified basic on food items, thickness of the package, weight, particles, each time point of surface and center temperature, and the surface temperature and time when the center temperature over the standard. The resulting clusters of objects should then exhibit high internal homogeneity and high external heterogeneity (Joseph *et al.*, 1998).

## 3. Results

### 3.1. Frozen sample

#### 3.1.1. Time-temperature changes

Recorded temperature showed that the center and surface product temperature were vary. For example, we observed the ice product's center temperature is below  $-18^{\circ}\text{C}$ , however, the surface temperature exceed up to  $-12^{\circ}\text{C}$  for 3 to 33 minutes after took out and stored in controlled environment. Fig. 1 showed the temperature changes in four

Sample No.	Sample	Packaging materials	Thickness (mm)	Weight (g)
(1)	tea	Tetra Pak	0.42	322
(2)	tea	plastic	0.35	675
(3)	tea	Tetra Pak	0.70	421
(4)	milk	Tetra Pak	0.46	316
(5)	milk	glass	2.55	443
(6)	milk	cartons	0.96	318
(7)	juice	plastic	0.65	456
(8)	juice	glass	2.25	474
(9)	honey herbal	Tetra Pak	0.62	373
(10)	honey herbal	cartons	0.80	509
(11)	coffee	aluminum can	0.52	381
(12)	coffee	plastic	0.23	649
(13)	coffee	glass	2.03	434
(14)	coffee	Tetra Pak	0.42	408

Table 2 The thickness and weight of chilled samples.

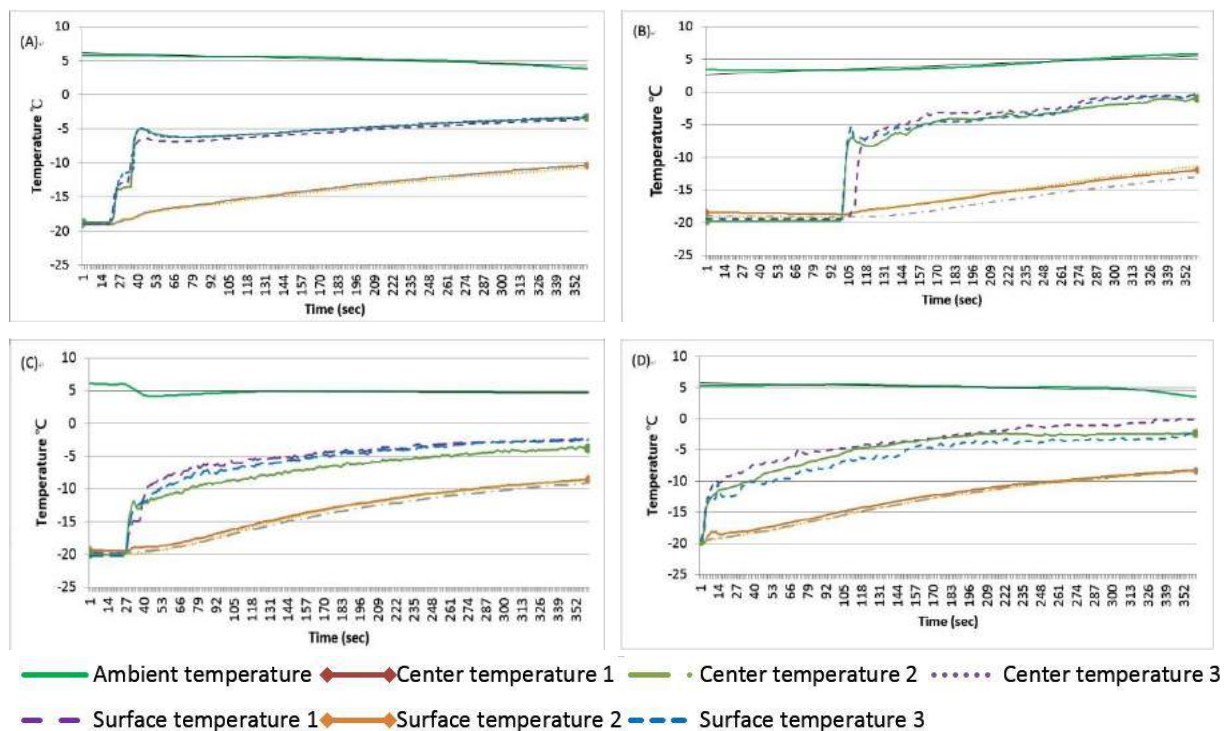


Figure 1 Temperature changes of frozen samples. (A) snow pie (B) sweet cream (C) strawberry flavor (D) chocolate flavor

types of ice product. The correlation between the center temperature and the surface temperature of each ice product is found to be between 0.663-0.985. It meant that the center temperature and the surface temperature have high positive correlation, therefore, the center temperature is predictable from the surface temperature.

### 3.1.2. Time/temperature analysis of different types of ice products.

Ice cream products were divided into three main group by hierarchical clustering, and categorized in large, medium, and small group, separately. Fig. 2 showed the dendrograms of large ice cream (chocolate flavor), medium ice cream (snowy pie, strawberry flavor, chocolate flavor, Hawaiian flavor, milk flavor, and red bean paste), and small ice cream (sweet cone).

The large, medium, and small weight of ice cream is 392, 81, and 74g, respectively. The thickness of the packaging were found to be 96.46, 46.23 to 74.12, and 58.44 mm, respectively. The average temperature of the large, medium, and small weight was  $-5.4 \pm 2.0^\circ\text{C}$ ,  $-9.96 \pm 2.0^\circ\text{C}$ , and  $-5.7 \pm 1.2^\circ\text{C}$ , respectively. During the evaluation, the surface temperature was rose up to  $-12^\circ\text{C}$  after 23, 5 to 19, and 11 minutes, respectively.

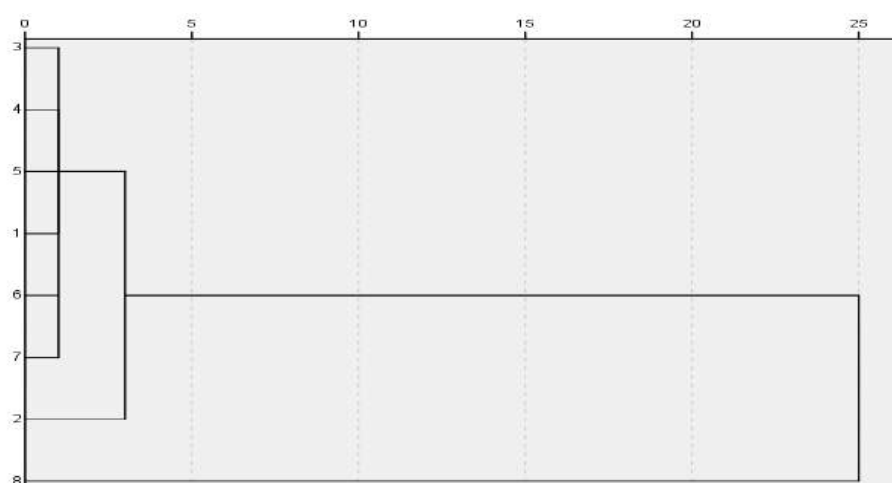


Figure 2 Hierarchical cluster analysis of frozen samples. 1. (A) snowy pie 2. (B) sweet cone 3. (C) strawberry flavors 4. (D) chocolate flavors 5. (E) Hawaiian flavors 6. (F) milk flavor 7. (G) red bean paste 8. (H) chocolate flavors.

Additionally, it was also observed that large ice cream lose temperature faster.

## 3.2. Chilled samples

### 3.2.1. Time-temperature changes

After 19 to 58 minutes, 13 kinds of beverages surface temperature exceeded the limit temperature of 7°C, rose up to 7.3 to 9°C, except the center temperature of aluminum can coffee samples. The correlation between the center temperature and the surface temperature of each kind of beverage is between 0.956–0.999 (Fig. 3). The correlation of the surface temperature measured by the infrared thermometer and measured by the probe were between 0.644–0.944. Similar to the frozen temperature, the center temperature of these products can be predictable by obtaining the surface temperature.

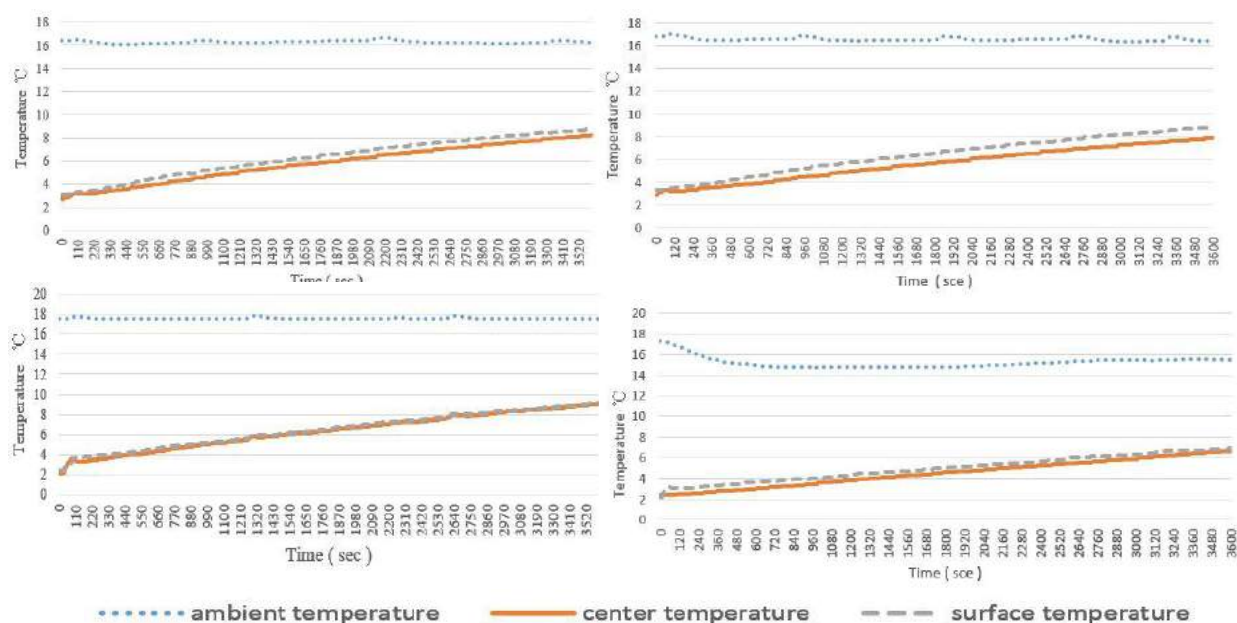


Figure 3 Temperature changes of chilled samples (A) carton milk (B) plastic orange juice (C) Tetra Pak coffee (D) aluminum can coffee.

Additionally, we also observed that product surface temperature was well described by the temperature recorder by infrared thermometer.

### 3.2.2. Time / temperature analysis of different types of beverages

Beverages were divided into six main group by hierarchical clustering, and named the group from (i) to (vi), separately (Fig. 4). Group (i) contains Tetra Pak tea, carton milk, Tetra Pak milk, carton milk, and Tetra Pak milk. Group (ii) contains aluminum can honey herbal, and aluminum can coffee. Group (iii) contains plastic juice, carton tea, Tetra Pak coffee. Group (iv) contains carton honey herbal. Group (v) contains glass milk, glass juice, and glass coffee. Group (vi) contains plastic tea, and plastic coffee. The weight of Group (i) range from 316.5 to 322.0 g, and the average thickness of its package material is 0.61 mm. At constant temperature, the average center temperature higher than 7°C after 43 minutes and the average surface temperature is 7.4°C. The weight of Group (ii)

ranged from 373.8 to 381.5 g and the average thickness of the package material is 0.57 mm. At constant temperature, the average center temperature higher than 7°C after 47 minutes and the average surface temperature is 7.5°C.

The weight of Group (iii) ranged from 408.5 to 509.3 g and the average thickness of the package material is 0.59 mm. At constant temperature, the average center temperature higher 7°C after 48.8 minutes and the average surface temperature is 7.8°C. The weight of Group (iv) ranged from 509.28 g and the average thickness of the package material is 0.7 mm. At constant temperature, the average temperature higher than 7°C after 59 minutes and the average surface temperature is 8°C. The weight of Group (v) ranged from 434.7 to 474.1 g, and its package material is glass, the average thickness of the glass is 2.28 mm. At constant temperature, the average center temperature higher 7°C after 21.6 minutes and the average surface temperature is 8.1°C. The weight of Group (vi) ranged from 649.5 to 675.7 g and the average thickness of the packaging material is 0.29 mm. At constant temperature, the average center temperature higher 7°C after 34.5 minutes and the average surface temperature is 11.6°C.

#### **4. Discussion**

The temperature abuse are happening in temperature-controlled logistics industry in Taiwan, particularly in chilled and frozen product. This result is similar behavior with the result that reported by Zubeldia *et al.*, (2016) in Spain. The author reported that over 50% of the refrigerated temperature was non-compliance for the food categories of vegetables, fishery products, mixed products, global foodstuffs, dairy products and meat products. In another major study, Lundén *et al.* (2014) observed the temperature violations in 50% of the refrigerated products. Surprisingly, a 17.9% of these products exceeded the temperature limit by over 3°C for more than 30 min in Finland.

Attempting to understand this phenomenon in this study, we found there have high correlation between surface and central temperature, the frozen one is between 0.663-0.985, chilled one is between 0.956-0.999. Furthermore, the observed beverages' surface temperature measured by probe and infrared thermometer have high correlation between 0.644-0.944. The main impact factor for high correlation is the weigh. The more weigh of the beverages associated with surface area caused the product temperature lost faster. Moreover, while the central temperature of chilled product was 7°C, the surface temperature was in the range of 7.4-8.1 °C. Similarly, in frozen food, the central temperature was -18°C, but the surface temperature was in the rage of -15.4--3.2°C and the median was -7.9°C. With respect to the regulation of low-temperature food in Taiwan,

we suggest the limit of the surface temperature should be revised to 8°C in chilled beverage and -8°C in frozen food. However, it has to note that the limit of -8°C in frozen food was suggested for particular food ice cream product.

Taking into account that the nature for most manufacturers are generally measuring the surface temperature of the food product, therefore, understanding this behavior provides better understanding of the product center temperature. Hence, collecting and measuring the temperature along the food cold chain enhances the food safety effort and prevents cold chain interruption.

## **5. Conclusions**

This paper presented the aspects of the relationship between the surface and center temperature for frozen and chilled food. In summary, the data provided in the article indicated that product surface temperature has a high correlation with the center product temperature. However, it has to note that may be there are another factor affected the measurement of food temperature, therefore, future research is need in this area. In addition, with respect to the regulation of low-temperature food in Taiwan, we suggest the limit of the surface temperature should be revised to 8°C in chilled beverage and -8°C in frozen ice cream. Taken together, these results can be used as a reference used by food safety authorities in Taiwan in food regulatory-making process to ensure the public health protection.

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# **OPERATING PROCEDURE AND TIME-TEMPERATURE DATA TRANSPARENCY IN HOME DELIVERY COLD CHAIN LOGISTICS**

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## **Abstract**

**Introduction:** Due to changing eating habit of consumers, demand for home delivery services of chilled and frozen food is increasing in Taiwan. However, due to its special characteristics, home delivery service providers face difficulties on temperature control, such as too frequent door opening and closing, which can lead food safety and quality loss problems. Operating procedure in logistics process for chilled and frozen food home delivery service providers is an area that is under researched and under discussed.

**Purpose:** In order to reduce food safety and quality concerns, this research aims to explore current status of hygiene and temperature control of frozen and chilled food home delivery service providers, and suggest operating guidelines and consider possibility of sharing time-temperature data with customers.

**Method:** A home delivery service provider in Taiwan involved in the study was selected. Data loggers were used to monitor actual temperatures. Two diagnostic tools were used: One is the current good hygiene practice (GHP) for food logistics providers, another one is proposed operating procedure from survey results from food manufacturers conducted in 2015. The overall research involved two stages before counseling and after counseling for establishing operating procedures.

**Results:** Temperature control can be significantly improved after establish operating procedure. However, home delivery service providers still suffer temperature uncertainty of consumer packages when receiving; and too frequent door open when transporting. To prevent from losing trust from consumers or government, we proposed that home delivery service providers should consider use continuous temperature monitoring and sharing with consumers.

**Value:** The findings offer a novel view for food home delivery service providers to improve cold chain logistics management which broadens the scope from pure theory perspective to operating procedure.



## 1. INTRODUCTION

The chilled and frozen foods are perishable items and very sensitive to environmental conditions such as temperature, humidity and light etc. This make cold chain logistics management a challenging area (Bogataj, Bogataj, & Vodopivec, 2005; Bruckner, Albrecht, Petersen, & Kreyenschmidt, 2012). Most of cold chain studies have indicated controlling and maintaining the temperature all along the cold chain is difficult because some of steps are especially weak, such as loading and unloading, transport, display cabinet (Derens-Bertheau, Osswald, Laguerre, & Alvarez, 2015; Koutsoumanis, Pavlis, Nychas, & Xanthiakos, 2010; Montanari, 2008). These unexpected temperature loss can lead to food safety problem and loss of consumer confidence (Chen, Zhang, & Delaurentis, 2014; Derens-Bertheau, et al., 2015; Knowles, 2002; Nychas, Skandamis, Tassou, & Koutsoumanis, 2008; Röhr, Lüddecke, Drusch, Müller, & Alvensleben, 2005).

Due to changing eating habit of consumers, demand for home delivery services of chilled and frozen food is increasing (Ghajargar, Zenezini, & Montanaro, 2016; López & Ferrándiz, 2016). However, due to its special characteristics, home delivery service providers face difficulties on temperature control in Taiwan, such as too frequent door opening and closing, which can lead food safety and quality loss problems (Chen et al., 2011; Chou & Lu, 2009).. Operating practice in logistics process for chilled and frozen food home delivery service providers is an area that is under researched and under discussed. In 2013, a good hygiene practice (GHP) for food logistics industry is developed in Taiwan. One of requirement is that a food logistics company should develop a standard operating procedure for logistics flow. A standard operating procedure is written practices and procedures that are critical to delivering safe food and remaining food quality. In order to reduce food safety and quality concerns, this research aims to suggest operating guidelines for home delivery service providers in chilled and frozen logistics flow and consider possibility of sharing time-temperature data with customers.

## 2. LITERATURE REVIEW

The survey taken in 2015 to food manufactures who owned vehicles showed that cold chain capability should consist of four factors: ability to manage speed, ability to manage hygiene, ability to manage temperature and ability to response. This cold chain capability was proved to be related with cold chain logistics performance. Temperature management is important. Food deterioration induced by microbial and chemical activities takes place rapidly when perishable products are exposed to temperatures between 5°C and 60°C (Adamberg, Kask, Laht, & Paalme, 2003; Membre et al., 2005). For example, the number of *Bacillus cereus* in cooked chicken rice products stored at 10°C reached 10<sup>7</sup> CFU/g after 3 days of storage (Ayari,

Dussault, Hamdi, & Lacroix, 2016). Additionally, formation and growth of ice crystals when products are exposed to temperatures between -5°C and 0°C (Giannou, Kessoglou, & Tzia, 2003; Kaale, Eikevik, Rustad, & Kolsaker, 2011). Speed: Tamimi *et al.*, 2010: it is recommend moving fast when temperature-controlled food are put improper temperature condition because of quality and food safety consideration. For example, better route planning to shorten transportation time and distance, or enough storage room for fast cooling product temperatures (Fuller, 1998). Hygiene: hygiene is one of factor relating food quality and food safety. Maintaining hygiene in transportation vehicle and storage room, isolation between frozen and chilled storage, first-in-first-out principle based on shelf-life are some of hygiene practices (FAO · 2003). Ability to response referred having emergency plan which specifies procedures for handling sudden or unexpected temperature loss or shut down of cooling system. Based on these four factors, our survey in 2015 suggested steps and activities should be taken by food manufactures in additional to GHP.

### **3. RESEARCH DESIGN**

#### **3.1. Field study design**

A home delivery service provider in Taiwan involved in the study was selected to explore current status of hygiene and temperature control. This home delivery service providers was initialed in 2000 in Taiwan, nowadays it owns more than 2000 workers and 500 vehicles. In addition, for its home delivery services, four distribution centers, and more than 100 service points are used for its operations. In food categories, it offers delivery services for food products in room temperatures, chilled and frozen temperatures from home to home services, or from convenience store to convenience stores services within 24 hours. In this case, our research team offers counseling service to help the company to establish standard operating procedure through generation of temperature profiles and diagnostics tools.

#### **3.2 Generation of temperature profiles**

Data loggers (HOBO, USA) were used to monitor actual temperatures of food distribution flow. We placed 12 data loggers in following areas to monitor environment temperatures: chilled and frozen cold room, rechargeable frozen fridge, loading dock and chilled and frozen transport vehicles (four for each). The overall experiment period lasted one week and temperature was recorded every minute. Operation time spent in each step was obtained through interviews to company manager.

### **3.3 Diagnostic tool to assess cold chain logistics performance (hygiene, temperature control)**

Two diagnostic tools were used to assess hygiene and temperature control performance for this home delivery providers. One is current GHP for food logistics providers which focusing on environment and workers (not shown). Another one is proposed operating procedure of frozen and chilled logistics process developed from survey results from food manufacturers in 2015 (see Table 4).

## **4. RESULTS AND DISCUSSION**

### **4.1 Temperature profiles**

Table 1, 2 and 3 shows temperature recording outcomes before counseling and after counseling. Table 1 shows temperature profiles of chilled vehicles before and after counseling. Results indicated that percentage of temperature abuse ( $>7^{\circ}\text{C}$ ) in chilled vehicle was largely reduced from 74% to 46%. Similarly, percentage of temperature qualification ( $\leq -18^{\circ}\text{C}$ ) in frozen vehicle was largely increased from 3% to 19%. Table 3 indicated that percentages of  $0^{\circ}\text{C}\sim 15^{\circ}\text{C}$  range can increased from 36% to 95%. Similar improvements can be found in chilled and frozen cold room (data not shown).

### **4.2. Diagnostic outcomes of cold chain logistics performance (hygiene, temperature control)**

GHP and Table 4 were used to evaluate cold chain logistics performance with focus on hygiene and temperature control. Evaluation results of GHP shows that this company needed to improve following points:

1. Environment: Trash was found in handling areas, it is suggested that the environment should be kept clean anytime.
2. Workers (1) workers should close door anytime during handling areas; (2) personal belongs such as drinks should not put in cold room.
3. General issues: (1) rechargeable fridges should upload right away; (2) cold room or vehicles should use temperature alarm in order to remind workers; (3) pre-cooling is needed in order to prevent temperature loss before loading; (4) a standard operation procedure is suggested in this company.

Table 4 shows differences between survey in 2015 and home delivery service provider in operating procedure of frozen and chilled food logistics. Compared to food manufacture's operating procedure, home delivery service provider has following difficulties to follow. Receiving: Product temperature should be measured

and recorded. Product temperature should meet requirements of chilled food at 0-7 °C for chilled food and -18°C for frozen food. Transporting: product temperature should meet requirements of chilled food at 0-7°C for chilled food and -18°C for frozen food.

Derived from our findings, temperature abuse problems that home delivery service providers have may come from temperature uncertainty of consumer packages because they are not able to check temperature status of the packages; and the other one is that too frequent door opening than other logistics service providers or food manufacturers. To prevent from losing trust from consumers or government, we proposed that home delivery service providers should consider use continuous temperature monitoring in cold room or vehicles. Monitoring time-temperature and having real-time information is useful because immediate decisions on quality or safety can be made based on the temperature profile of the supply chain. To maintain effective cold chain management, recording and tracking the temperature of food through the supply chain is an important step (Bogataj, et al., 2005; Montanari, 2008; Hsiao and Huang, 2016).

Table 1. Temperature profiles of chilled vehicle

	before	after
>7°C	74%	46%
0°C~7°C	26%	30%
-1°C~0°C	0%	24%
Highest	25.90°C	24.64°C
Lowest	3.37°C	-6.75°C
Average	11.41°C	7.60°C

Table 2. Temperature profiles of frozen vehicles

	before	after
>-1°C	42%	34%
-1°C~-5°C	20%	11%
-5°C~-18°C	35%	36%
≤ -18°C	3%	19%
Highest	26.88°C	24.55°C
Lowest	-24.17°C	-26.70°C
Average	-1.6°C	-4.24°C

Table 3. Temperature profiles in handling areas

	before	after
>15°C	64%	5%
0°C~15°C	36%	95%
-1°C~0°C	0%	0%
Highest	23.96°C	18.66°C
Lowest	9.08°C	6.28°C
average	16.12°C	11.72°C

## 5. CONCLUSIONS

Temperature control can be significantly improved after establish operating procedure. However, home delivery service providers still suffer temperature uncertainty of consumer packages when receiving; and too frequent door open when transporting. To prevent from losing trust from consumers or government, we proposed that home delivery service providers should consider use continuous temperature monitoring and sharing with consumers. Overall, an effective home delivery cold chain management is needed to make sure that all kinds of chilled or frozen food products with different temperature requirements can be and are maintained at the best quality condition.

**Table 4. Differences between survey in 2015 and home delivery service provider in operating procedure of frozen and chilled food logistics.**

Steps	Activities (proposed by survey in 2015)	Company A
Receiving	Product temperature should be measured and recorded.	Difficult to follow
	Product temperature should meet requirements of chilled food at 0-7°C for chilled food and -18°C for frozen food.	Difficult to follow
	Environment should be maintained below 15°C Or, operations time should be controlled within 30 minutes under 15°C to prevent dynamic temperature fluctuation.	Easy to follow
Storing	Cold room should function properly in order to maintain product central temperature at chilled temperatures at 0-7°C for chilled food and -18°C for frozen food.	Easy to follow
	Frozen and chilled products should be stored in different cold rooms.	Easy to follow
	Temperature fluctuation should be avoided.	Easy to follow
	Alert system is needed when cold room temperature is higher than required temperature.	Easy to follow
	Emergency plan is needed in case of refrigeration system is out of order.	Easy to follow
	Personnel hygiene education and environment hygiene control is needed.	Easy to follow
Value-added	Environmental temperature should be kept at 7 degree.	Not relevant

activities	Place for processing ready-to-eat food should be isolated well for preventing cross-contamination.	Not relevant
	Selection of packaging material should guarantee not polluted from environment during transportation and storage.	Not relevant
	Personnel hygiene education is needed.	Not relevant
Loading	Environmental temperature should be kept under 15 degree. Or operation speed should be fast, recommend within 30 minutes under 15 degree for preventing temperature fluctuation and formation of water drops on	Easy to follow
	Product temperature should meet requirements of chilled food at 0-7°C for chilled food and -18°C for frozen food.	Easy to follow
Transporting	Loading docks should be installed dock shelter.	Easy to follow
	Precooling is needed and should be at below 10 degree. Or before loading, environmental temperature should be able to maintain food product central temperature fulfill chilled food products.	Easy to follow
	Stacking properly and cold air should be flowed properly.	Easy to follow
	Door curtains are needed in order to prevent temperature loss.	Easy to follow
	Emergency plan is needed when cooling system is out of control.	Easy to follow
	Product temperature should meet requirements of chilled food at 0-7°C for chilled food and -18°C for frozen food.	Difficult to follow
	Temperature fluctuation should be avoided.	Difficult to follow

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# EFFECTS OF CONSUMER-PRODUCTS MATCHING ON PRICE SETTING PROBLEM FOR PERISHABLE PRODUCTS

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## ABSTRACT

This paper describes a price setting problem for a perishable product to maximize the expected revenue. Such a situation is apparent in sales of fresh green vegetables or used cars. For the problem, we present a consumer behaviour model characterized by a joint probability distribution in which the price and demand are initially random variables. Secondly, we present a consumer-product matching model designed for computer simulation. The model represents a certain condition of our consumer behaviour model in which the demand distribution is fixed. According to computer simulations comparing outcomes with various parameter settings, effects of a consumer's expected price distribution are strongest.

**Keywords:** Fresh foods, Inventory theory, Stochastic model, Computer simulation

## INTRODUCTION

The value of fresh foods as represented by green vegetables and fresh fruits is expected to decrease as time progresses after they are harvested. The value also changes dynamically according to the demand and supply balance, depending on the harvested amount. We confront the difficulty of having a large amount of unsold goods if we set a high price for fresh foods. However, if we set a lower price for fresh foods, we will obtain insufficient revenue. Our research has emphasized a rational means of determining the price of fresh foods under given conditions. This dilemma is apparent in price setting problems related to used cars and second-hand smartphones. These items have similar characteristics: conditions of the items mutually differ. Moreover, their current value is expected to decline.

Many studies have investigated decisions related to perishable products. The Newsvendor problem (Hiller & Lieberman 2011) is a representative one. Under a given demand probability distribution, it determines a prepared stock level of goods sold at a fixed price. The sold price is previously determined is a characteristic of the Newsvendor problem. The relation between price and sales amount in elasticity of price has also been discussed. Therefore, not only the amount of stock but also the price should be regarded as a decision variable.

Takeno et al. (2013b) presented an investigation of the price setting problem at a farmer's market where a farmer sells his products directly to consumers. In that problem, the farmer's revenue depended on their strategy of price setting, which differs according to the shipping volume. Takeno et al. (2015) presented a model for the price setting problem as an extension of the Newsvendor problem. In the model, customer demand is represented and explained with a joint probability distribution in which price and sales amounts are employed as stochastic variables.

As described in this paper, we extend a consumer behaviour model using a joint probability distribution proposed by Takeno et al. (2015). We assessed the relation among price, demand, and sales to ascertain the probability of selling out. Secondly, we specifically examined the matching process between a consumer and a product. We extend a computer





Figure 1 Inside a Farmers' Market.

simulation model of Takeno et al. (2015) by considering details of consumer behaviour, which is represented as a consumer search process in the market.

We first explain a Farmers' Market, which is our research field, and the fundamental problems they must confront. Secondly, we present a consumer behaviour model that incorporates relations among price, demand, and sales. Next, we show a computer simulation model incorporating consumer behaviours and outcomes. Finally, we conclude this paper and describe remaining work.

## **FARMERS' MARKET**

Farmers' markets have become an important distribution channel for fresh agricultural products in Japan during the last two decades. Farmers sell their products directly to consumers at a store. The person who produced the product might be well known or identifiable. Therefore, the products satisfy consumer demands related to food safety. In Japan, such stores are called Sancho: direct sales at production sites.

Farmers' markets require the participation of customers, farmers, and a manager who is a representative of farmers and the shop. Shelves inside the shop are assigned to farmers. Farmers prepare and manage their products on these shelves. Consumers come to the shop and select products from these shelves. They settle payments with a cashier, as in a supermarket, while farmers are able to work and spend time performing farming tasks. Occasionally, farmers visit the store to confirm the inventory. Farmers can replenish the products if the stock level dips below a certain level. After closing the store, the manager calculates the total sales for the day and informs each farmer of the total sales.

Farmers must choose their own production, shipment, sales, and other operation parameters. However, the core competency of farmers is agricultural production, especially for medium-scale and small-scale farmers. Therefore, they have insufficient knowledge and methods to manage their businesses at farmers' markets. A certain amount of support for their store business is necessary to manage and run the store. Utilization of an information system can be a beneficial solution.

Takeno et al. (2013b) conducted a questionnaire investigation and presented some analyses of farmers' decision making processes. Through that investigation, they clarified that farmers can be categorized into three groups according to their production size. Price setting of medium-scale farmers is almost identical to the average price of the market. Those of large-scale farmers and small-scale farmers are, respectively, lower than average and higher than average because large-scale farmers prevent themselves from holding dead stock of perishable products. We have specifically examined the strategy of small-scale farmers. Because of quantitative limits on products they have on hand, they must

set a higher unit price to achieve a higher income. However, a high unit price is unfavourable and unacceptable by consumers. Therefore, as the market strategy for small-scale farmers, it is important to seek the highest unit price that is favoured and accepted by consumers.

### **SINGLE PERIOD PRICE-DEMAND MODEL FOR PERISHABLE PRODUCTS**

A price-setting problem for perishable products such as fresh green vegetables can be considered. A product size, weight, and appearance all vary. The product is sold in units as a piece, bag, box, etc. The product prices differ according to the unit value. However, the market price is given from past data. In general, we are inclined to believe that a lower price is more attractive. For the product, the lower price might be attributable to lower quality of the unit of the product, such as smaller contents or inferior appearance. Here we expect to determine the optimal price of the product under the effects of the stock level and competitive products' prices.

Presuming a random variable  $X$  which corresponds to amount of customers' demand, one can define a probability density function  $g(x)$ , where  $P(X \leq x)$  corresponds to the probability of being sold out when the inventory level of the good is set to  $x$ . Also,  $g(x)$  represents almost identical meaning to the News Vendor Problem in which a random variable  $X$  is a continuous value. In the model, the price of the good is assumed as a constant value. After presuming a random variable  $Y$  that corresponds to the good price, one can define a probability density function  $h(y)$ , where  $P(Y \leq y)$  corresponds to the probability of being sold out when the price of the good is set as  $y$ .

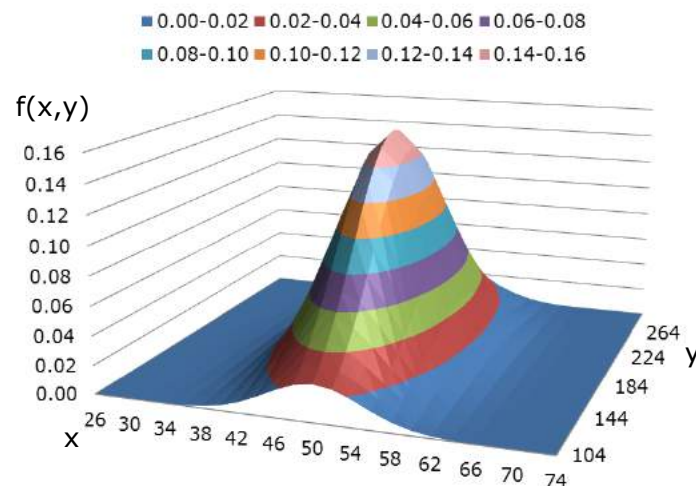


Figure 2 Example of joint probability density distribution  $f(X, Y)$ .

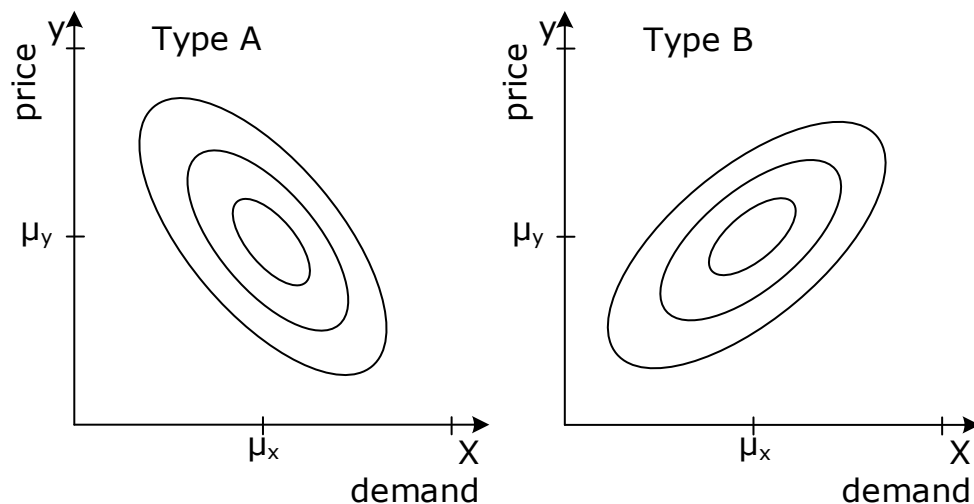


Figure 3 Characteristics of distribution derived from parameter settings.

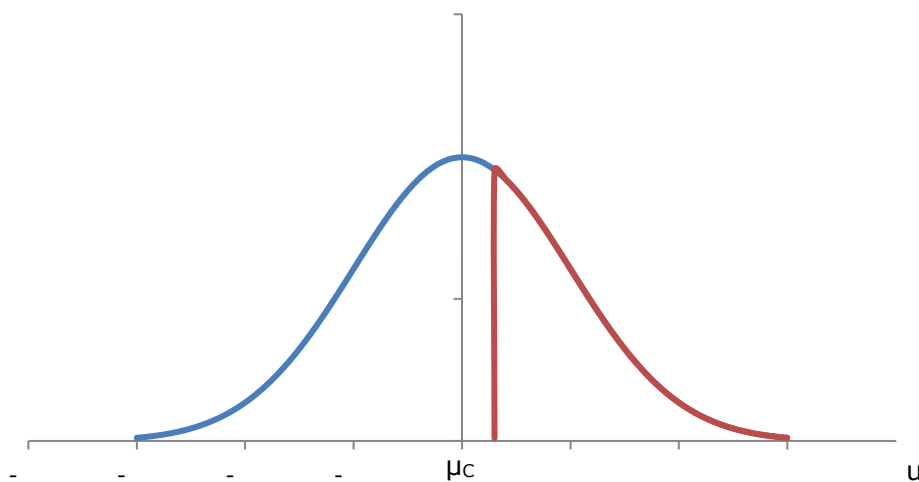


Figure 4 Relation among  $P_1$ ,  $\mu_c$ , and  $P_2$ .

Assuming a Joint Probability Density Function  $f(X,Y)$  where  $X$  and  $Y$  are defined as shown above, then Figure 2 presents an example of the Joint Probability Density Function. As the figure shows, the distribution shape might differ by combinations of parameter settings. Figure 3 shows typical characteristics represented with the proposed joint probability density function. A normal distribution is not assumed for these examples. Horizontal and vertical axes show demand  $x$  and price  $y$ . Ellipses show higher probability density areas, i.e. potentially sold out. Type A represents a situation in which a low price and high demand occur. Such a situation is often seen for many goods. Type B represents an item for which many people want to buy a newer model, e.g. recent smartphones.

### **SMALL-SCALE FARMER'S PRICE SETTING MODEL**

More concretely, we discuss the price setting problem that confronts small-scale farmers. To maximize their income, farmers must set the price of their product higher than that of a large-scale farmer. Here, we assume that a consumer will pay for product A up to his expected price, i.e., the upper limit price. Because the upper limit price varies on each customer, we present a series of numerical experiments to show effects of variance of the upper limit price.

Presuming a farmers' market at which customers buy product A with two farmers participating in the market, one farmer is Farmer  $F_1$ , a large-scale farmer, whereas the other is Farmer  $F_2$ , a small-scale farmer. Consumer  $C_i$ ,  $i = 1, 2, \dots, n$ , has upper limit  $U_i$  on

the price at which he buys product A.  $U_i$  is a random variable that has a normal distribution with parameters  $\mu_c$  and  $\sigma_c$ . Let  $P_1$  and  $P_2$  respectively denote a price of A produced by large-scale farmer  $F_1$  and  $F_2$ . According to Takeno et al. (2013b), the large-scale farmer tends to set a price lower than the other. Therefore,  $P_1 \leq \mu_c < P_2$ . Let  $S_1$  and  $S_2$  respectively represent the shipping volume of product by farmers  $F_1$  and  $F_2$ . From the definition,  $S_2$  is much smaller than  $S_1$ ,  $S_2 \ll S_1$ . Let  $\rho$  be a ratio of production amount of  $F_2$  to that of  $F_1$ ,  $\rho = |F_1|/|F_2|$ . We have  $0 < \rho < 1$ . In an actual farmers' market,  $\rho$  is expected to be about 0.01.

Figure 4 presents the relation among  $P_1$ ,  $\mu_c$ , and  $P_2$ . The horizontal axis and vertical axis respectively show the price and probability density of  $P(U_i < u)$ . Upper limit price  $U_i$  is distributed as shown by the blue line, partially covered with a red line. At  $P_2$ , the price of product a by farmer  $F_2$ , is larger than  $\mu_c$ . Probabilities of sales on  $F_2$  are limited to the area enclosed by red lines. In other words, the probability indicated with the enclosed area corresponds to the opportunity to sell for farmer  $F_2$ .

The model presents a relation between  $U_i$  and  $P_2$ . If  $P_2$  gets larger, then the price of each product gets higher. However, the number of the sold product becomes smaller as the area enclosed with red line gets smaller. If  $P_2$  gets smaller, then the price of each product decreases. Furthermore, the number sold will increase. The problem is to seek a suitable price  $P_2$  to obtain the highest sales for farmer  $F_2$ . Because  $\rho$  is set as a small value,  $P_2$  will not affect the sales of farmer  $F_1$ . The problem is apparently a Newsboy problem, as explained by Hiller and Lieberman (2010) and others. However, the product A price is given as a random variable in the problem, whereas the number demanded is given in the Newsboy problem.

### CONSUMER-PRODUCT MATCHING

Takeno et al. (2015) presents a series of numerical experiments related to consumer-product matching. The model consists of a consumer, denoted as X, of agricultural product A. Consumer X has the upper limit price  $U_x$  for product A, where  $U_x$  is generated randomly with normal distribution  $N(\mu_c, \sigma_c^2)$ . Let  $P_1$  and  $P_2$  be prices of product A produced respectively by Large-scale farmer  $F_1$  and Small-scale farmer  $F_2$ .

First, Consumer X is assigned randomly to products  $F_1$  or  $F_2$  according to the ratio of production amount  $\rho$ . Then the consumer decides to buy the product if  $P_1 \leq U_x$ , otherwise not, as shown in Figure 5. The model presents the possibility of selling Small-scale farm products. Nevertheless, it does not consider the consumer X purchase process sufficiently.

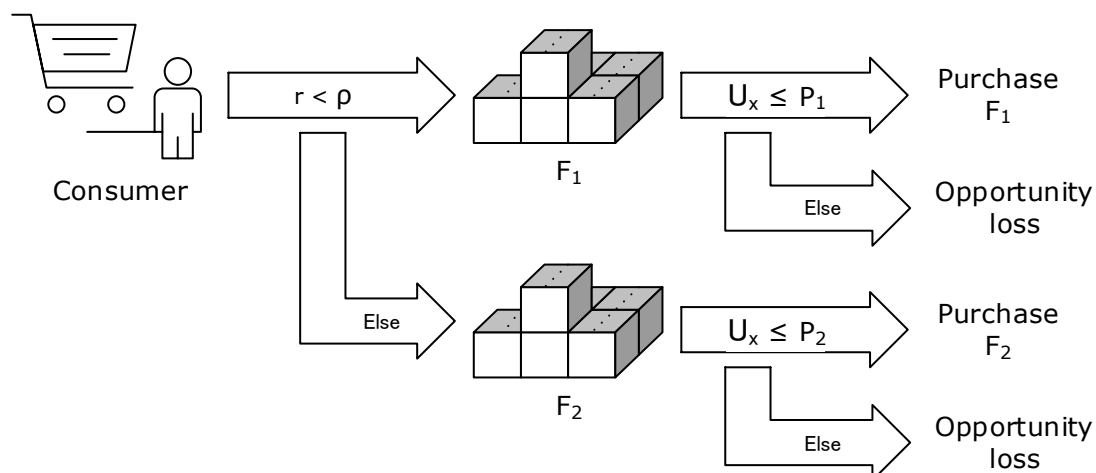


Figure 5 Consumer-product matching model of Takeno et al. (2015).

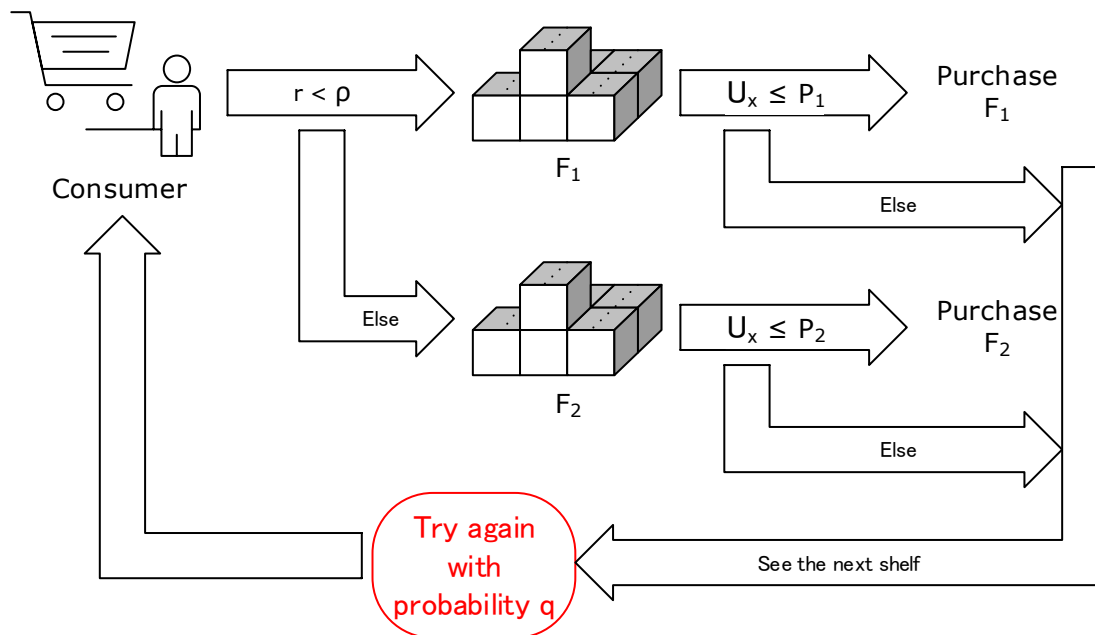


Figure 6 Consumer-product matching model considering the comparison process.

We extend the Takeno et al. (2015) simulation model considering consumer behaviour by which a consumer compares another product. A consumer tries another product with probability  $q$  if a consumer's expected price  $U_x$  is greater than  $P_1$ , where  $0 \leq q < 1$ . When  $q = 0$ , the simulation model behaviour is identical to that described by Takeno et al. (2015), as shown in Figure 6.

### Numerical Experiment

We conducted a numerical experiment for a model with the situation that the number of consumers and inventory at the market is identical. In other words, number of consumers  $n = (S_1 + S_2) = 10,000$ . We also have assumed that  $P_1 = \mu_c = 1000$ . First, we prepared 10,000 consumers with upper limit price  $U_i$ . Here, each  $U_i$  is generated using Box-Muller methods. Second, we prepared 10,000 products of which prices are selected randomly from  $P_1$  or  $P_2$  according to  $p$ . Table 1 presents a description of the experimental environment. We have varied several combinations of  $p$ ,  $\sigma_c$ , and  $q$ . The calculation time for the combinations is less than 1 min.

Figures 7 and 8 show the outcomes. The horizontal axis shows the standard deviation of consumer's price  $\sigma_c$ . The vertical axis shows the sold out data for small-scale farmer  $F_2$ . No product A is sold if it is 0%, where 100% corresponds to selling out. Each line corresponds to a difference of the ratio of production amount  $p$ . The try-again probability  $q$  is prepared with four variations: 0.00, 0.25, 0.50, and 0.75. Outcomes of  $q=0.00$  were referred from Takeno et al. (2015). Furthermore, two mean prices of small-scale farmers were adopted: 1100 and 1200. They were set higher than the mean market price  $\mu_c$ .

As shown in the tables, for 1100, some outliers are apparent, although the value is the mean of 10,000 trials. For cases greater than 100,  $\sigma_c$  becomes larger if the try-again probability  $q$  increases. According to results of our numerical experiment, the try-again probability  $q$  has somewhat stronger effects than the ratio of production amount  $p$ . The case of  $q=1200$  shows the same tendency as that for outcomes of  $q = 1100$ . However, the probability of being sold out is much smaller than for  $q = 1100$ , meaning that the price has much stronger effects on this problem.

### CONCLUSION

As described in this paper, we specifically examined the price setting problem of a small-scale trader. We have therefore reported the practical problem of a farmer's market. We proposed a single period price-demand model for a perishable product. The model is

characterized with integration of a traditional newsvendor problem and a price setting problem of Takeno et al. (2013b), where a joint probability distribution is for explanation. The model is expected to be useful to explain the relation between a customer's demand and the sold price. We also presented a couple of related utilization examples.

We conducted a numerical experiment. The adopted model was extended from Takeno et al. (2015) to elucidate consumer behaviour by introducing try-again probability  $q$ . Through the experiment, we demonstrated that the possibility of selling out of inventory of a small-scale farmer depends strongly on the variance of consumer behaviour, i.e. the upper limit price. By increasing the try-again probability  $q$ , the sold out probability is also increased. However, the effect of  $q$  is not strong. This tendency is independent of the mean price of the small-scale farmer.

Table 1 Experiment Environment

CPU	Intel Core i7-3930K	Operating System	Windows 10 Pro
Memory	16.0GB	Coding language	Visual Basic 2015
Calculation time	< 1 min		

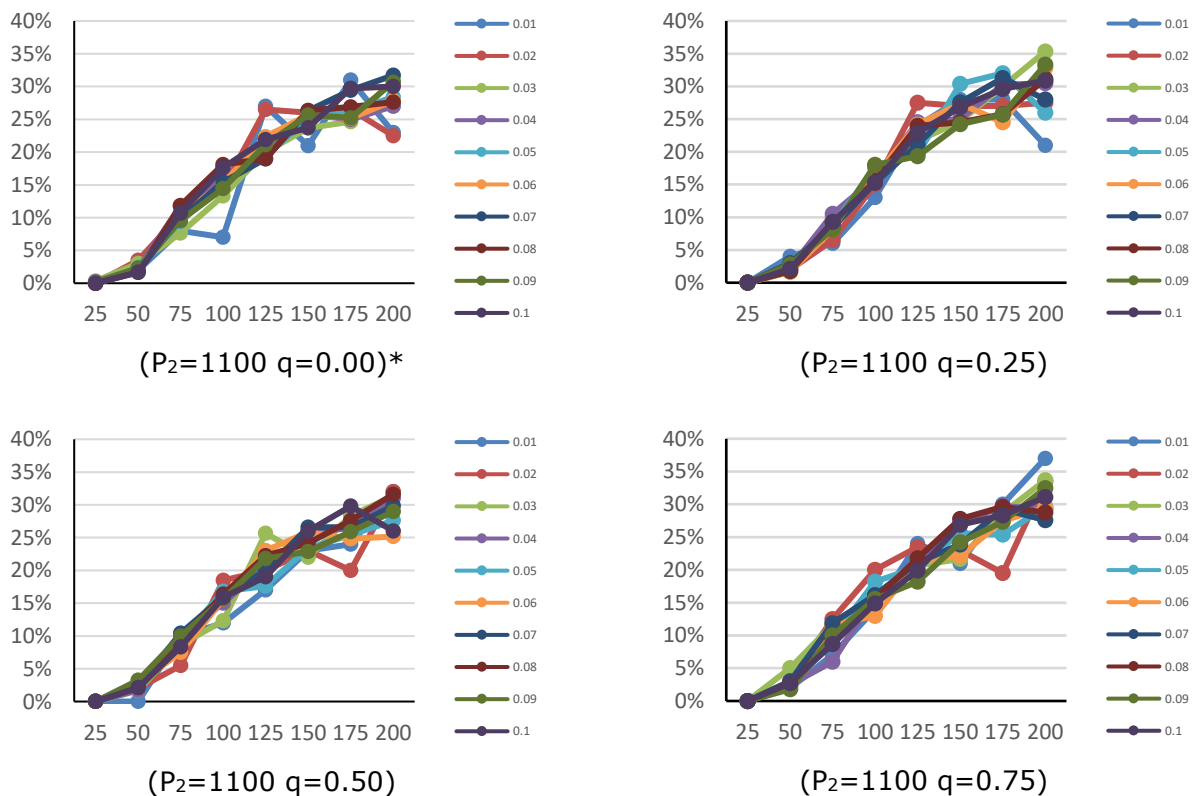


Figure 7 Effects of consumer behaviour in case of  $P_2=1100$ .

\*: referred from Takeno et al. (2015)

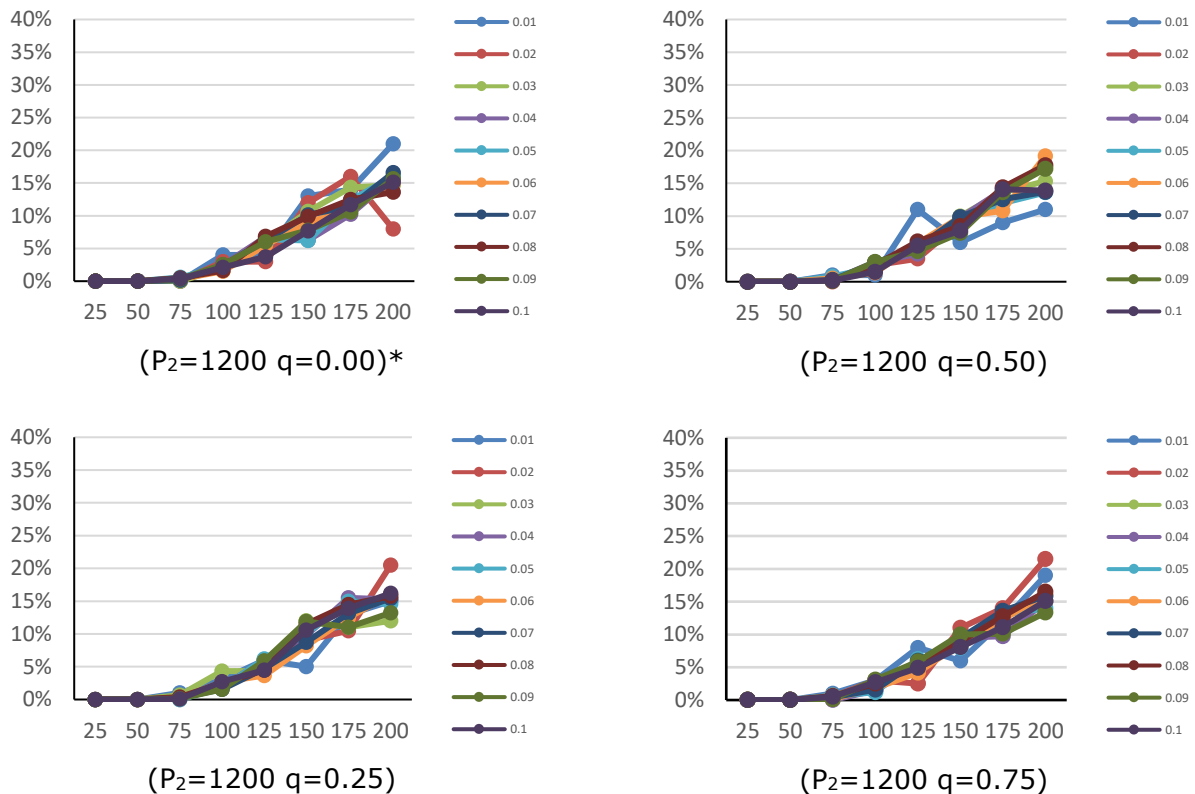


Figure 8 Effects of consumer behaviour in case of  $P_2=1200$ .  
\*: referred from Takeno et al. (2015)

Future studies will be conducted to establish a mathematical model to calculate the most profitable price setting for small-scale farmers under conditions of a given customer's behaviour represented in  $\sigma_c$ . For numerical experiments, matching processes should be improved and be more varied. We must consider additional situations and matching processes between consumers and products. Furthermore, price setting methodologies addressed in this paper are expected to be useful for price setting with another niche product. Investigations of such products are anticipated as an important avenue for future work.

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# PRODUCT CHARACTERISTICS FOR DIFFERENTIATED REPLENISHMENT PLANNING OF MEAT PRODUCTS

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## ABSTRACT

**Purpose:** Meat products have different demands, shelf life and supply lead-time causing increased risk of waste and unavailability. As meat products are unfit for storing this raises the need for effective, efficient and differentiated replenishment planning throughout the supply chain. This, in particular for the wholesaler not having any control of the production of products but merely balancing diverging and converging product and information flows. Current planning frameworks mainly focus on production planning and sharing of information between producer and customer at product group level, rather than at wholesaler and individual product level. This article aims to provide a conceptual framework for differentiating the effective and efficient replenishment of meat products.

**Design:** Design of replenishment of meat products needs to be designed on product characteristic and not on at product group level, since meat product with a group may have different product characteristics due to e.g. shelf life and supply lead-time causing increased risk of waste and unavailability. We have developed a proposed a conceptual replenishment-planning model based on four main characteristics for particularly fresh meat product that supports differentiated planning and replenishment.

**Findings:** By taking into consideration four main characteristics for particularly fresh meat product, it is possible to identify how replenishment planning should differentiate in planning for different fresh meat products, at individual product level.

**Value:** This paper is amongst the first to address how to differentiate the planning of demand and supply of food products with short shelf life, at individual product level rather than group level, according unique product characteristics. It has value for researchers as it provides direction for future research to demonstrate how use of unique product characteristics may influence the ability to plan differentiated. For practitioners the values is in providing a framework for how to group deteriorating products reducing the risk of waste from deteriorated products.

## 1. INTRODUCTION

Grocery business consumers have ever-growing requirements for low price, constant availability, high quality (i.e. product freshness) and broad variety (Fernie et al., 2010; Jacobsen and Bjerre, 2015). Special for meat products, they have time-dependent scarcities in supply since their raw materials (i.e. animals) have different lifetimes when slaughtered, up to two years. Further, different meat products have dissimilar demand and (short) shelf life making them unfit for storing. Replenishing all products in the same undistinguishable way merely relying on stock building, causes increased risk of waste from expiration and profit loss (Mena et al., 2014). This makes the effective, efficient and differentiated planning of replenishment of products utmost important. In particular, since product availability influences customer loyalty (Kuhn and Sternbeck, 2013).

Current fresh food planning frameworks incorporating product characteristics (i.e. shelf life) mainly focus at manufacturers' production planning (Entrup, 2005; Romsdal, 2014)



and, information sharing between supply chain stages for improving performance (Alftan et al., 2015; Kaipia, 2009; Kaipia et al., 2013) rather than wholesalers and directional guidance as how to operationalise the planning. Further, rather than individual product level current frameworks focus on the internal planning of product groups (Entrup, 2005; Ivert et al., 2015; Romsdal, 2014), differentiating via forecasting-, production strategy- and/or inventory management-oriented segmentation (van Kampen et al., 2012). This includes e.g. order characteristics (lead-time, shelf life, temperature etc.) and demand characteristics (seasonality, fluctuation, frequency etc.) (Boylan et al., 2008; Hanke and Wichern, 2009; Hübner et al., 2013; van Kampen et al., 2012; Williams, 1984).

This influences wholesaler's ability to effectively and efficiently plan negatively; first, since wholesaler does not have any control of the production of products (Hübner et al., 2013) but merely facilitates the converging and diverging information and product flow through replenishment. Second, since the products are different in terms of supply lead-time, demand and shelf life. Third, since deteriorating, the products are unsuitable for longer time storing requiring limited time from order dispatch to order arrival. One replenishment cycle governs the time from an order is placed (or production is initiated) until the order has arrived (or completed) (Nahmias, 2005; Silver et al., 1998). Since no storing, and, between 40 days to more than two years' production time (i.e. growth-/life-time) of animals, it is relevant to investigate how replenishments should be planned (and differentiated) through product level-based classification. By taking into consideration four main characteristics for particularly fresh meat products, it is possible to identify how the replenishment planning should differentiate. Focus is on fresh meat products with up to 14 days shelf life. The following presents theoretical background, followed by investigation of four key-characteristics (forecasting and demand behaviour, supply lead-time and growth time, degradation and shelf life, and, frequency and intermittent demand), presentation of conceptual framework, and finally discussion and conclusion.

## 2. THEORETICAL BACKGROUND

A main goal when balancing demand with supply throughout the supply chain is to share information enabling the forecasting of future demand, causing timely replenishments which allow demand to be met instantly when occurring – effectively and efficiently (Hübner et al., 2013; Lambert, 2008). Where traditional replenishment (on non-deteriorating products) relies on building inventories to meet demand and withstand fluctuations, based on a trade-off between inventory costs and service level to customer, deteriorating products needs a trade-off between waste (since inventory turns into waste due to short shelf life) and service level.

When determining the quantity to replenish, numerous models exist to accommodate an optimized order dispatching for deteriorating products (Bakker et al., 2012; Goyal and Giri, 2001; Raafat, 1991), relying on the newsvendor problem (Silver et al., 1998). However, apart from merely determining the order size, efficiency is gained in higher degree when choosing optimum order rules – i.e. when to initiate the ordering of the products (Nahmias, 2005; Silver et al., 1998). The quantity to order may be either fixed for all replenishments ( $Q$ ), or, variable and represent the required amount to reach a certain level ( $S$ ). Time for order may similarly be either fixed interval ( $R$ ), or, variable interval ( $s$ ) – that is when inventory level drops below a predefined level (i.e. re-order point (ROP)). However, Wensing (2011) and Silver, et al. (1998) additionally highlight the situation of way of reviewing inventory levels. Adding more complexity, time-point for reviewing inventory levels may either be at fixed times ( $R$ ), or, continuous ( $R=0$ ) – that is when  $R \rightarrow 0$ . In total five policies are possible: ( $s, S$ ) and ( $R, s, S$ ) suitable for A-times, and, ( $s, Q$ ), ( $R, s, Q$ ) and ( $R, S$ ) suitable for B-items (Silver et al., 1998). However, meat products requires a different approach. Since degrading with constantly increasing chance of expiring (causing waste) and no longer storing of products is desirable, meat products must be evaluated against waste costs and the actual deterioration of the product instead.

Since different products behave differently through time, this raises the need for appropriate classification of meat products securing the relevant differentiation. Following van Kampen et al. (2012) the context (i.e. fresh meat products) and aim (i.e. planning of replenishments<sup>1</sup>) of the classification influences the choice of characteristics. Given the limitations in currently classification methods, interest thus lies in investigating the different characteristics for fresh meat products and their inter-relations. As for the number of characteristics to choose, van Kampen, et al.'s (2012) note that no consensus seem to exist and in general up to ten characteristics are used – however, without clear argumentation for choosing this number.

Meat products constantly deteriorates through time, and are highly volatile to factors alike seasons and weather, leaving them with a latent uncertainty and particularly high variation in demand. Four characteristics are found relevant for grouping the meat products. Since meat products deteriorate, storing for longer time is undesirable, meaning the ability to forecast with high precision is important, making demand variation the first parameter. Connected to this is the shelf life, ranging from only few days to 14 days, requiring different tolerance and sensitivity to storing (e.g. fish with maximum storing of one day versus grounded beef with a few days) – thus also overestimation and oversupply. Thirdly is supply lead time, that is, the time it takes from an animal is born until it is ready for slaughtering, ranging from 40 days (i.e. chicken) to more than two years (i.e. cow). The last characteristic is (customer) ordering frequency, since meat products may not have demand constantly due to days without demand, closing days, holidays, additional opening, etc. This influences the planning and forecasting methods using lag indicators. The parameters are explored in greater depth, in the following.

## **2.1 Variation in Demand and Forecasting**

Forecast drives planning of demand (Hübner et al., 2013) and consumers' purchases in shops set the supply chain in motion. This makes the ability to forecast as accurate as possible to efficiently and effectively replenish products and fulfill downstream demand a first step in providing customer service (Lambert, 2008). As consolidator in the supply chain, wholesaler must be able to interpret and plan efficiently and effectively to expected level of demand (Kuhn and Sternbeck, 2013), "to be more proactive to anticipated demand and more reactive to unanticipated demand" (Lambert, 2008, p. 87), in turn influencing implications when moving up the supply chain (i.e. reducing bullwhip effect) (Chen et al., 2000).

Improvement of forecasting is a "key factor for improving supply chain operations in the food industry supply chain" (Adebanjo, 2009) to create a cost-effective supply chain. Apart from time-horizon to forecast, the prediction of future demand relies in significant degree on choice of forecasting method, which in turn ultimately relies on demand pattern (Hanke and Wichern, 2009). Demand across all products does not behave in same way (Adebanjo, 2009), and frequently ordered product's demand behaviour may be characterized according to four different types of pattern: horizontal, trend, seasonal and cyclical (Hanke and Wichern, 2009). Adebanjo (2009) classifies products based on product type, in regards of required effort in determination of demand (steady, seasonal or promotional), each with different requirements and level of supply chain collaboration, ranging from low to high. He further claims that a diversified approach for predicting future demand leads to significant savings and increased supply chain performance. Additional to this classification of products, with great impact on the accuracy of forecasting, is the variation in demand. The more stable demand the greater reliability and less attention required when forecasting, thus the greater suitability for automated forecasting. Similarly, the less stable demand, the less reliability and greater need to attention when forecasting. To evaluate this, the coefficient of variation (CV) is suitable. CV is a measure of spread describing the variability relative to the mean in a unit less manner. This allows the different products to

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<sup>1</sup>In the original framework production strategy is used, yet, since wholesaler balances divergent and convergent information and product flows (Hübner et al., 2013) instead of production, replenishment planning is used.

be compared, and thus found one dimension for grouping products in terms of differentiated replenishment planning.

## 2.2 Shelf Life of Fresh Food Products

Since fresh meat products immediately (after production) degrades in quality constantly, interest is in incorporating the shelf life when planning. Shelf life is defined in different ways: practical storage life (PSL), high-quality life or noticeable difference (usually used for fruits and vegetables). For the purpose of this article PSL is suggested, and is defined by IIR (International Institute of Refrigeration) as "the period of storage at that temperature during which the product retains its characteristics properties and remains both suitable and acceptable for consumption or the intended purpose" (Evans, 2016). Though seeming similar to e.g. frozen and chilled products, meat products remain more complicated since up to 14 days shelf life from production. Whereas chilled food, and in particular frozen, products are fit for up to several months (even years) of storing, fresh meat products have down to few days' shelf life, e.g. sushi, grounded fish and Boeuf bourguignon with shelf life of five days from production. Planning replenishment relying on identical stock building approach for all products, not consideration the different products' deterioration, causes increased risk of waste from expiration and profit loss.

The product's shelf life (or food quality) follows the quality index' kinetic function. The loss in quality through time ( $\partial A / \partial t$ ) is essentially described as  $-\frac{\partial A}{\partial t} = kA^n$ , where  $A$  is quality index value,  $k$  is rate constant (dependent on temperature, product and packaging characteristics), and  $n$  is the "reaction order which defines whether the rate of change is dependent on the amount of  $A$  present" and the shape of the deterioration curve if environmental factors are constant (Fu and Labuza, 1997, p. 4). The curves may have different shapes (see left graph in Figure 1): linear (a), exponential (b), hyperbolic (c), quadratic (d) or complex (e) function (Fu and Labuza, 1997).

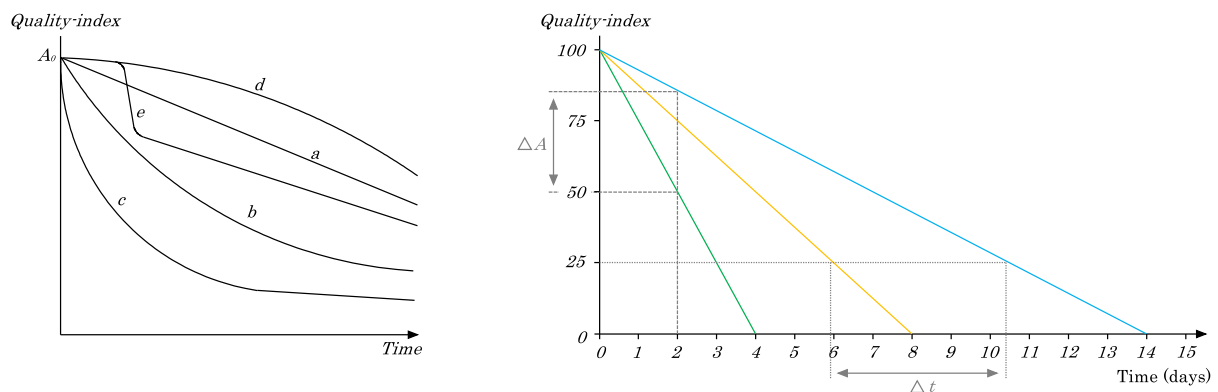


Figure 1: Deterioration Curves (left) from Fu and Labuza (1997), with an Example of Linear Deterioration Curve for Different Products in Relation to Quality and Time (right)

The right graph in Figure 1 illustrates the relationship between quality-index and time; for reasons of simplicity and illustration, the following assumes a linear deterioration curve (that is  $n = 0$ ) for three products. As meat products start degradation immediately after production, any time-period until delivery is critical and influences the level of quality in the product. Assuming  $A_0$  is the immediate moment after production (quality level = 100), two days influences the product significantly, with decrease in quality index of approximately 30 (see dotted lines  $\Delta A$ ). Similarly, when looking at specific quality level, there is more than four days in difference before reaching e.g. quality level 25 for two products (see dotted lines for  $\Delta t$ ). For order dispatching, this means a trade-off must be met between cost-based quantity and quality-based quantity. Saying this, a purely economic order based model assume products have indefinite amount of storage lifetime. However, because of the deterioration, a quality-based takes this into consideration and thus per se suggests lower amounts to purchase when planning. Consequently, more orders will be dispatched to supplier in order to fulfil same demand, in turn causing increasing ordering costs. To overcome this Bakker, et al. (2012) and Goyal & Giri (2001)

provide literature overview of different inventory ordering models taking this into consideration. Given the scope of this article, further attention is delimited.

### 2.3 Supply Lead Time of Animals

Related to forecasting is the supply lead time, that is the time it takes to grow the raw material (i.e. animal) before it is ready for the given meat product. Planning replenishment of meat products is influenced by latent scarcity (in their raw materials) from a certain point in time. From the time point an amount of animals is given birth and starts to grow, no additional amount of raw materials is available per se. This, since meat products are not subject for longer term storing, contrary to other types of products. Also, different animals have different time windows for being acceptable for use in meat production, to ensure uniform product quality and avoidance of damages to the animals (e.g. if living for too long time chickens grow too big and break their feet). If exceeding these time-windows the animals become unfit for production, i.e. waste. Table 1 shows the different animal-groups' growth time (until ready for slaughtering) and time-window for being acceptable for slaughtering, following Danish Agriculture and Food Council.

Chicken	Pork	Beef	Fish, examples
≈ 40 days	≈ 5-6 months (90-105 kilos)	<10 months (veal) 10-24 months (young cattle) >24 months (cow-beef)	>40-60* cm (salmon) >25-27* cm (flounder) >30-35* cm (cod)

*\*depends on the catching-area (North Sea, Baltic Sea, Kattegat, etc.) and sea-type (salt- or freshwater)*

Table 1. Age/Size of Animals Slaughtering & Catching Time

Chicken and pork have the shortest life times, with respectively 40 days and five to six months (depending on a weight between 90 and 105 kilograms). Consequently, these groups also have the shortest forecasting horizons compared to the other product groups. However, they have a time-window of acceptance for production of only few days and one month, respectively, before causing waste, in turn, requiring a comparable greater level of attention when planning. Beef has a stepwise evolvement without any further delimitating time-window. Split into three types of beef, then, if the animals become too old for being classified as veal (more than 10 months), they merely re-classify and change type to young cattle. Similarly, if becoming too old for this classification (more than 24 months), they change type to cow-beef where "the-bigger-the-merrier"-principle applies. Fish are influenced by factors alike e.g. nature, climate and nutrition available in the water, and thus caught and slaughtered according to size instead of age, with no predetermined amount of growth time. Instead, "the-bigger-the-merrier"-principle applies, meaning, the bigger fish means greater value (i.e. revenue).

These differences influence not only the preciseness in forecasting but also the type of forecasting (long term versus short term forecasting), and the attention and the effort needed in planning replenishment. Moreover, where chickens' replenishment cycle is short and influences only short-term planning (< 6 months), pork is on the border of influencing medium-term planning (6-12 months) and beef influences long-term planning (>12 months) (Hübner et al., 2013). Hence, meat products' replenishments require life-time-based differentiation in planning, sharing of demand information (with differentiated influence of replenishment on demand and supply planning) and level of collaboration.

### 2.4 Ordering Frequency of Products

In regards of frequency, van Kampen, et al. (2012) find one particular popular criterion: order frequency, representing the frequency a products is ordered e.g. annually. By using this in replenishment planning, it takes into consideration whether a product is ordered often or not. Specifically for meat products, this is of interest due to the deterioration. The less frequency, the less time per period the product is ordered, hence the greater attention required when ordering. Common forecasting techniques assume a constant demand (i.e. demand in each inventory period) – however, not all products face such constant demand, e.g. campaign products, seasonal products and low selling products. This hence influences replenishment planning in great degree – including the forecasting. E.g., if applying common exponentially smoothing forecasting techniques in planning, greater weight will

be attained latest observation – which may be zero due to the demand pattern. In turn, this will interrupt the forecast and cause negative influence and increased risk of either over- or understocking. Hence, as demand patterns are not identical for all products and differentiate, Eaves & Kingsman (2004, p. 432) highlight that “it is useful to classify line items according to their observed demand pattern and perhaps use alternative methods when demand is intermittent or slow moving”.

The products with infrequent demand, Williams (1984) groups as either smooth, slow moving or intermittent. Boylan, et al. (2008) state in their framework that a non-normal product's demand can be intermittent, slow moving, erratic, lumpy or clumped. Determining what is non-normal demand, Eaves & Kingsman (2004, p. 432) note, “with intermittent items the observed demand during many periods is zero interspersed by occasional periods with irregular nonzero demand”. Boylan, et al. (2008, p. 474) further point out that “infrequent demand occurrences or irregular demand sizes, when demand occurs, do not allow lead time to be represented by the normal distribution”. Varghese & Rossetti (2008) highlight different definitions of intermittent demand, hereunder e.g. as “many time periods with zero demand”, series with at least 30% of zero demand” and “series with less than or equal to 60-70% non-zero demand”.

#### 4. CONCEPTUAL REPLENISHMENT PLANNING MODEL

Having four characteristics, a four-dimensional space is required and here many simple classification techniques falls short. Each characteristic is divided into up to three groups (low/short, medium or long/high), and represent in combination the suggested conceptual model for planning demand and supply of fresh meat products, see Table 2.

	<b>low</b>	<b>medium</b>	<b>high</b>
Coefficient of variation	The product has stable and predictable demand, where reliable forecast is possible. Little attention is needed for forecast, and product is subject for possible automation. Relatively lower SS and ROP is required.	The product has less stable demand and less reliable forecast with significant forecast errors. Forecast require post-evaluation with possible adjustments. Depending on variation, ROPs and SS need re-evaluation periodically.	The product has instable demand, significant fluctuations and unreliable forecast with very significant errors. Forecast require significant attention and constant monitoring of demand. Manage products, SS and ROPs closely and adjust accordingly.
	<b>slow</b>	<b>medium</b>	<b>fast</b>
Degrading speed	The product has long shelf life (i.e. PSL) up to several days, even weeks. When ordering use EOQ-based order size calculation.	The product has mixed shelf life (i.e. PSL) ranging from few days to several days. When ordering use either quality- or EOQ-based order size calculation.	The product has short shelf life (i.e. PSL) up to only few days. When ordering use quality-based order size calculation, and, manage and monitor inventory level closely.
	<b>short</b>	<b>medium</b>	<b>long</b>
Supply lead-time	The product has short supply lead-time with fast response time from supplier and thus relatively lower latent uncertainty. Forecast daily and initiate replenishments accordingly. Send forecasts to internal operations and supplier.	The product has medium supply lead-time with medium response time from supplier and relatively higher latent uncertainty. Initiate replenishments on daily basis as needed, and forecast medium-term sales with regular review and adjustment. Forecast may be input to medium-term other planning aspects, may thus be forwarded internally – and externally (in case of campaigns).	The product has long supply lead-time with low response time from supplier and thus high latent uncertainty. Initiate replenishments on daily basis as needed, and forecast long-term sales, with frequent review and adjustment – with principle of general overestimation (due to life-time window). Forecast may be input to other medium-/long-term planning aspects, and may this be forwarded internally.
	<b>high</b>	<b>medium</b>	<b>low</b>
Order frequency	The product is ordered very frequently (if not each day), and has relatively lower risk for long storage. Given a higher turnover, less attention is needed and product may be subject for automatic order generation (or automotive replenishment).	The product is ordered infrequently and possibly a cyclical product. Manage and monitor products closely, analyse and understand demand and adjust SSs and ROPs periodically	The product is ordered rarely (possibly seasonal), has lower turnover and thus faces a relatively higher risk of long storage time. Manage and monitor products closely, analyse and understand demand and adjust SSs and ROPs accordingly.

Table 2; Replenishment Guidelines for Product Classification

For coefficient of variation, high value mean less reliable forecast and thus high attention required to RP&C. On the other hand, low valuation means high reliability in forecast and thus requiring less attention to the planning. In fact, the lower valuation, the greater potential has the product of having automated replenishment. For supply lead-time, long means higher uncertainty in planning and additionally greater influence on quality degradation of the products, qua the accordingly higher inventory levels. Low lead-time indicates less uncertainty in planning and less influence on quality level, making these products' replenishment very flexible. In particular, supply lead-time is influenced animals' lifetime, and vary not only within each animal's lifetime (pork may deviate up to one month since 5-6 months' lifetime), but also latent between different animals (chicken has lifetime of 40 days where e.g. fish has unknown lifetime). For deterioration, the higher level the more attention required and the greater trade-off between costs and quality. Deteriorating very fast, inventory levels are maintained with greater focus. On the contrary, low level allow a less requiring management. The lower degrading speed, the more tolerance for economic order quantity-based management. Finally, for order frequency high valuation means very frequent request of product. For planning this influence the decision making in regards of quality. The higher order frequency, the less influence has the degradation. If a product has, high frequency (ordered often) – inventories are *influenced* through lower levels and thus lower risk of obsolescence. Hence, the lower frequency the greater attention to forecast and planning (recall non-normal demand patterns). When grouping e.g. demand variation as either high, medium or low different authors point out that boundaries between each of the categories is essentially a management decision (Eaves and Kingsman, 2004; Williams, 1984). Therefore, the grouping is not quantitatively shown (with cut-off values), but rather illustratively suggested for the different conceptual groups of products.

	<b>Grounded beef 8-12%</b>	<b>Sushi-box 9pcs.</b>	<b>Chicken breast w/ barbeque</b>	<b>Pork filet w/ tomatoes &amp; oregano</b>
Shelf life	8 days	5 days	11 days	14 days
Supply lead time	+ 2 years	up to 1 year	40 days	5-6 months
Coefficient of variation <sup>1</sup>	0.618	0.137	1.920	1.090
Frequency	1.000	0.958	1.000	0.247

<sup>1</sup>Coefficient of variance is based on sample data, and thus an unbiased estimator for sample size  $n$  is used.

Table 3; Example of Values for Classification from Four Different Products

As example four different products are classified, see Table 3. Compared to one another, replenishment planning of grounded beef has influence on medium- and long-term planning, and requires long-term forecasting. Since constant demand and relatively low coefficient of variation, with medium shelf life, it may be subject for automated replenishment with manual adjustment for campaigns and seasonal fluctuation. Sushi box requires, although low coefficient of variation, close monitoring since relatively longer supply lead time and low shelf life with no constant demand. Chicken breast has constant demand, with medium/long shelf life and relatively short supply lead-time, hence forecasting and replenishment may be automated, despite the high fluctuation. Hence, check for campaign and seasonal fluctuation. Pork filet requires closest attention during replenishment planning, since very infrequent demand (despite long shelf life) and medium/longer supply lead-time.

## 5. CONCLUSION & FURTHER RESEARCH

The background for the study is the increasing focus on low price, wide assortment, high quality in and constant availability of fresh food products, raising the need for low cost, differentiated, efficient and effective planning. This to avoid reduction in profit base from wasted (i.e. deteriorated) products. Where current frameworks for planning take stance within certain level of uniform approach, the unique and diversified characteristics of each products seem to be overlooked. Although there is increased focus on green and sustainable supply chain performance, the risk of facing waste from inefficient and

ineffective operations and decision making (i.e. food waste) remains. Further research is proposed to govern testing of the framework across a range of meat products with short shelf life range to determine its influence on planning of demand and supply, as well as the influence on performance in planning. Further, it is suggested to test the framework across a broader range of products with short-to-medium(-to-long)-term shelf life such as chilled and frozen food products, to test its general applicability for other products.

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# DATA DRIVEN CLOSE LOOP SUPPLY CHAINS FOR SUSTAINABLE LOGISTICS OF THE MEAT INDUSTRY<sup>i</sup>

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## Abstract

**Purpose:** Data driven supply chain management is essential to operational efficiency, carbon footprint limitations, and satisfaction of customers. The principle objective of our study is to suggest a new data model of integrated processes of the meat industry in a close loop supply chain (CLSC), based on the ideas of extension of MRP to a reverse supply chain and on the developments of cyber-physical systems which are developing fast in a 4<sup>th</sup> generation industry. Like in the general spatial/urban studies also in the meat logistics chain the most important indicators of sustainability are energy consumption, land use, employment possibilities, waste production, food loss, food safety, and pollution. **Design:** For better integration, and visibility the extended MRP model is suggested as a skeleton on which the database of CLSC is constructed. This approach enables us to consider the product flows as units of analysis, and aim to reintroduce returned products and/or their components into the forward flow by implementing reprocessing operations such as recycling. **Findings:** In the meat industry, slaughterhouse waste consists of high portion of slaughtered animal that cannot be sold as meat or used as the meat products, also the used packaging material, made of iron, aluminium or plastic is similar to urban waste, therefore could be consider in joint outputs of industry and the waste of urban communities in the reverse activities of cogeneration plant (animal fat), biogas plant (other waste) and urban waste water treatments. **Value:** For all these outputs from the basic supply chain the data should be carefully collected in real time, processed and available in real time to management and control. How to achieve such results tied to the Bill of Materials and matrix of timing is presented here. In the literature mostly cost approach is available. Our Net Present Value approach enables to evaluate also perturbations in timing and other risk factors not observable in the cost approach, especially when Internet-of-Things is available as an infrastructure in which the cyber-physical system is developed based on a good database.

**Key words:** Meat supply chain, reverse logistics, lead time, net present value, transportation, sustainability, urban facilities, cogeneration, perishability

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## INTRODUCTION

### Meat CLSC presented as an extended MRP model

We classify activities of an integrated close loop supply chain (CLSC) of meat processing, delivery and recycling into four distinct sub-systems: manufacturing, physical distribution, consumption, and recycling, as described in papers of Bogataj and Grubbström (2012, 2013). In this paper, we shall add perishability dynamics to the previously developed model. Development of Internet of Things as the infrastructure for Cyber-Physical Systems with embedded system technologies and distributed sensor network has enabled implementation of Extended MRP theory by allowing capturing time delays caused by perturbations in simple algebraic expressions. Also in the meat industry various operating stages in the logistic chain can be represented by simple models of material transformations. In each processing cell values are added and/or costs incurred. At each process stage, there could be a supply and a demand or disposal to the landfill, to the biogas station, to the water treatment plant, or/and to a cogeneration plant. The flows of animals and meat in the CLSC influence transportation and perishability costs, as well as costs of activities in logistic nodes. Consequently, the Net Present Value (NPV) of cash flows generated by all activities performed in logistic chain could be evaluated and changed in real time without substantial time delay if decisions and actions are possible



because the data are available in real time as the events happened. The cost of flows between two processes depends on their location and the transportation mode used between them, as well as on the perishability characteristics of meat in the chain. Important in this context is also location of the reverse logistics activities and disposal units, knowing also the spill-over of negative pollution externalities. An integrated supply chain includes the purchasing of animals and other raw materials, manufacturing with assembly and/or extraction, and the distribution of produced goods to other production units, or to the final clients, where consumption defines the activity levels, finally also to the reverse logistic activities (see figure 1). In a meat supply chain, key variables that have to be considered for each activity are the activity level and timing, the inventory level, the perishability dynamics of meat, lead times and other delays as well as the transformation of data of these physical indicators to the economic performances. The objective is to achieve the maximal net present value (NPV) of activities in the meat supply chain (Bogataj and Bogataj, 2001, 2007, Grubbström et al, 2010). By reducing the quantity of waste which goes into the environment, supply chains may avoid costs of mitigation the pollution. As written in Bogataj and Grubbström (2013), if managers of a supply chain do not have to bear them, market prices and the resulting NPV do not reflect these costs accurately. Meat and other raw materials or components are delivered and stored in raw material warehouses at the production centres. From there they are withdrawn in the quantities as they are needed to the production centres. There raw materials and components are transformed into semi-finished (prepared for packaging) goods, and so on. Here the main question is when to include activities of the reverse logistics in a supply chain and how the increased percentage of recycling items in production affects the NPV of the total integrated chain. This is particularly difficult to evaluate when lead times are varying and perishability dynamics is quite intensive and changing. The compact analyses in the frequency domain, in which lead time perturbations may be studied analytically, make evaluation of perishability and timing in NPV much easier. It also has a close tie with supply chain control in material requirements planning (MRP) studies. This approach gives us good theoretical and practical results also for the extension of the analysis to distribution and especially to the reverse logistics part of a supply network further developed by Kovačić and Bogataj, (2015) and Kovačić et al (2015, 2017). Knowing better the data of parameters in the CLSC, the decision variables and parameters can be determined for improvements of NPV and related environmental criteria.

### **Monitoring and control of perishability dynamics**

Meat is one of the highly perishable foods, which unless properly stored, processed packaged and transported spoils quickly. Important data which should be consider in the dataset are data on quality of items in a flow of supply chain and the value of items regarding their shelf-life. The perishability dynamics of meat depends on various factors like pre-slaughter practices, age of the animal in the slaughtering process, handling during slaughtering, temperature controls during slaughtering, processing and distribution, preservation methods, packaging and storage by consumer (Battini et al, 2016; Cervený et al., 2009). Different technical operations are involved in slaughtering actions following one to another in a supply chain of meat industry. Inadequacy and therefore increased perishability at one stage results in a negative impact on the process or quality of items in the following stage (FAO, 91). The storage and transportation temperature, humidity and light as well as the acidity of the meat and the structure of muscular tissue also affect the perishability dynamics (Berkel et al., 2004). After few hours of slaughtering, muscles become firm and rigid because of the stress during the slaughtering process. Raw meat quality is reported to be severely affected by the stress conditions during slaughtering process and the slaughtering methods (Miller, 2002). For controlling enzymatic, oxidative and microbial spoilage, low temperature storage and chemical techniques are the most common in the industry today, but can be often perturbed so that the meat is exposed to risk that will not be bought. It is essential to store the meat at lower than 4°C immediately after slaughtering and during transport and storage as it is critical for meat shelf life, appearance and eating quality (Dave and

Ghaly, 2011) and therefore this influences the final prices achieved on the market. The characteristics of volatile compounds in meat in process differ so that each sort of meat has its own characteristic like odour and colour. Active packaging is one of the methods to extend the shelf-life of meat. The active materials absorb for example moisture and/or contain the antimicrobial ingredients and antioxidants to improve the performance of meat. One of the most popular active packaging technologies is, for example, *modified atmosphere packaging* (Smiddy et al., 2002), which acts as a barrier against contaminants. Adding also sensors in such a packaging system we can detect earlier any event when perishability dynamics increase over expected limits, because the sensors provide knowledge of freshness to alert increase of perishability dynamics in the packages of the cold supply chain, which require our immediate action by changing temperature, humidity, or even to decide different final destination in time, if we assume that the final customer will not buy the meat being exposed to factors which influence faster perishability dynamics. Such combination is called "smart packaging" as a packaging system to detect, sense and record any deterioration inside the meat package (Kuswandi et al. 2014) to improve the safety, quality and enhance warning regarding deterioration procedures during transportation, warehousing and delivering to the final user (Salinas et al., 2012, 2014). Such control should be a part of the data driven Cyber-physical system of a meat logistics (Grubbström et al., 2010).

## THE EXTENDED MRP MODEL AS A SKELETON OF CYBER-PHYSICAL SYSTEM FORMALISING A MEAT CLOSE LOOP SUPPLY CHAIN

### The model of four subsystems

There are four sub-systems and the processes are grouped into four sets of columns, representing production, distribution, consumption and recycling respectively. The activity vectors are denoted:  $\mathbf{P}_1$ ,  $\mathbf{P}_2$ ,  $\mathbf{P}_3$  and  $\mathbf{P}_4$  concerning the respective processes of the sub-systems. Finally,  $\mathbf{x}_k$  denotes input requirements to and  $\mathbf{y}_k$  outputs from sub-system  $k$ ,  $k = 1, 2, 3, 4$ , so that a whole  $\mathbf{x}$  may then be written as

$$\mathbf{x} = \begin{bmatrix} \mathbf{x}_1 \\ \mathbf{x}_2 \\ \mathbf{x}_3 \\ \mathbf{x}_4 \end{bmatrix} = \begin{bmatrix} \mathbf{H}_{11} & \mathbf{H}_{12} & \mathbf{H}_{13} & \mathbf{H}_{14} \\ \mathbf{H}_{21} & \mathbf{H}_{22} & \mathbf{H}_{23} & \mathbf{H}_{24} \\ \mathbf{H}_{31} & \mathbf{H}_{32} & \mathbf{H}_{33} & \mathbf{H}_{34} \\ \mathbf{H}_{41} & \mathbf{H}_{42} & \mathbf{H}_{43} & \mathbf{H}_{44} \end{bmatrix} \begin{bmatrix} \mathbf{P}_1 \\ \mathbf{P}_2 \\ \mathbf{P}_3 \\ \mathbf{P}_4 \end{bmatrix} = \mathbf{H}\mathbf{P} \quad \mathbf{y} = \begin{bmatrix} \mathbf{y}_1 \\ \mathbf{y}_2 \\ \mathbf{y}_3 \\ \mathbf{y}_4 \end{bmatrix} = \begin{bmatrix} \mathbf{G}_{11} & \mathbf{G}_{12} & \mathbf{G}_{13} & \mathbf{G}_{14} \\ \mathbf{G}_{21} & \mathbf{G}_{22} & \mathbf{G}_{23} & \mathbf{G}_{24} \\ \mathbf{G}_{31} & \mathbf{G}_{32} & \mathbf{G}_{33} & \mathbf{G}_{34} \\ \mathbf{G}_{41} & \mathbf{G}_{42} & \mathbf{G}_{43} & \mathbf{G}_{44} \end{bmatrix} \begin{bmatrix} \mathbf{P}_1 \\ \mathbf{P}_2 \\ \mathbf{P}_3 \\ \mathbf{P}_4 \end{bmatrix} = \mathbf{G}\mathbf{P} \quad (1)$$

Here,  $\mathbf{H}_{kl}$  is the input matrix concerning the need of items required by sub-system  $k$  from running processes in sub-system  $l$ . Grey-coloured elements of  $\mathbf{H}$  in (1) would be zero matrices in a typical standard case adding all nonzero in the last column in case, that the flows to recycling are going from each subsystem. The "net production", written  $\mathbf{z}$ , is defined as the difference between total outputs, and total inputs. If an element is negative, it needs to be imported, and if positive it can be exported from the system according to the general formula:

$$\mathbf{z} = \{\mathbf{z}_1, \mathbf{z}_2, \mathbf{z}_3, \mathbf{z}_4\} = \mathbf{y} - \mathbf{x} = \{\mathbf{y}_1 - \mathbf{x}_1, \mathbf{y}_2 - \mathbf{x}_2, \mathbf{y}_3 - \mathbf{x}_3, \mathbf{y}_4 - \mathbf{x}_4\} = (\mathbf{G} - \mathbf{H})\mathbf{P}. \quad (2)$$

For our closed-loop system, taking the assumptions of zero-valued matrices into account (special structures of  $\mathbf{G}$  and  $\mathbf{H}$ ), we have the interpretations as listed in Table 1, also considered as the ingredients of our database. The quality of meat decreases in the supply chain with the dynamics depending on temperature, humidity, and other environmental factors. Products have their total shelf life ( $SL$ ) from a farm to the end of usability and a price of products  $\mathbf{p} = \mathbf{p}(RSL)$  depends on the remaining shelf life ( $RSL$ ;  $\mathbf{p} = \mathbf{p}(RSL)$ ).  $RSL$  is the time from a certain moment of measurement the perishability dynamics and its factors, until the time when the product is still acceptable for consumption by a customer. Sensors report on it. Depending on supply-chain ambient

conditions, quality will decrease over time at varying rates, here described by dynamics  $\beta_i, \beta_{ij}$ . If the decay acceleration rate changes at the moment  $t + \tau$ , we can write:

$$RSL(t + \tau) = RSL(t) - \sum_j \sum_i (\beta_i \tau_i + \beta_{ij} \tau_{ij}) , \quad (3)$$

where  $\sum_j \sum_i (\tau_i + \tau_{ij}) = \tau$  and  $j$  is the index of a child node of the  $i$ -th chain node on the route from time  $t$  to  $t + \tau$ . When their potential price falls to the costs of their further manipulation in the chain, the control in cyber-physical system could require a redirection of the flow from the chain to the reverse logistics sub-system based on known path on the MRP tree and its planned path.

$\mathbf{z}_k$	$\sum_{l=1}^4 (\mathbf{G}_{kl} - \mathbf{H}_{kl}) \mathbf{P}_l$	Interpretation	Comment
$\mathbf{z}_1$	$\mathbf{G}_{11} \mathbf{P}_1 + \mathbf{G}_{14} \mathbf{P}_4 - \mathbf{H}_{11} \mathbf{P}_1 - \mathbf{H}_{12} \mathbf{P}_2 - \mathbf{H}_{14} \mathbf{P}_4$	Net production of items used in and delivered from production	"Standard" net production, to which recycled usable items $\mathbf{G}_{14} \mathbf{P}_4$ are added. Some items goes directly to recycling: $\mathbf{H}_{14} \mathbf{P}_4$
$\mathbf{z}_2$	$\mathbf{G}_{22} \mathbf{P}_2 - \mathbf{H}_{22} \mathbf{P}_2 - \mathbf{H}_{23} \mathbf{P}_3 - \mathbf{H}_{24} \mathbf{P}_4$	Net "production" of items distributed	Items from output of distribution (less those redistributed), reallocated geographically (and temporally), compared to inputs, some goes to recycling: $\mathbf{H}_{24} \mathbf{P}_4$
$\mathbf{z}_3$	$\mathbf{G}_{33} \mathbf{P}_3 + \mathbf{G}_{34} \mathbf{P}_4 - \mathbf{H}_{34} \mathbf{P}_4$	Net "production" of items consumed	Used items and "new" in the sense that they did not exist before as used. $\mathbf{G}_{34} \mathbf{P}_4$ are energy and gas returned to city consumption (cogeneration)
$\mathbf{z}_4$	$\mathbf{G}_{44} \mathbf{P}_4 - \mathbf{H}_{44} \mathbf{P}_4$	Net production of recycled items	Outputs from recycling activities possible to use later as components in production. Landfill is assumed as an unit inside recycling

Table 1. Net production sub-vectors (extension of Bogataj and Grubbström, 2013)

### Notation and required data

We shall use the following notation for data, advised to be collected in the meat CLSC database, explained in the table 2:

$\mathbf{H}; h_{i,j} \in \mathbf{H}$	Input matrix describing how many items ( $h_{i,j}$ ) from $i$ is needed to produce or to package one item in activity cell $j$ (no. of items)	$s$	The complex frequency in the Laplace transformed domain ( $h^{-1}$ )
$\mathbf{G}; g_{i,j} \in \mathbf{G}$	Output matrix (no. of items)	$\tilde{\mathbf{H}}(s)$	generalised matrix (in frequency)
$i, j$	Indexes of activity cells in a supply chain	$SL(k); RSL(k)$	Shelf life $SL$ ; the remaining shelf life $RSL$ at the node $k$ (hours)
$P_j$	Intensity of activities no/cycle in $j$ -th activity cell	$\beta_{ij}; \beta_i$	Decrease of $RSL$ per time unit between nodes $i$ and $j$ , and in node $i$ .
$h_{ij} P_j; g_{ij} P_j$	Intensity of flow from $i$ to $j$ ; intensity of reverse flow from $j$ to $i$	$\beta_{ij} \tau_{ij};$	Decrease of $RSL$ in transportation from $i$ to $j$
$\tau_j$	Lead time for the manipulation of item $j$ inside activity cell (hours)	$\beta_i \tau_i$	Decrease of $RSL$ in $\tau_i$ (hours)
$\tau_{i,j}$	Lead time for transportation of items from $i$ to $j$ (hours)	$\tilde{\mathbf{H}}(s)_{tr}$	Generalized basic transportation input-output matrix
$\tau$	Lead time matrix with element $e^{s\tau_{ij}}$ in its $j$ -th diagonal position, or 0.	$\mathbf{c}$	Multiplier at exponent of decreasing price per one unit of $RSL$
$b_{i,j} \tau_{i,j}$	Costs of transportation one unit of $i$ from $i$ to $j$ (eur)	$\mathbf{p}/\mathbf{p}^*$	Price vector/ perturbed price vector;
$\rho$	(continuous) interest rate	$\mathbf{K}$	Setup and other fix costs in the cycle (see Grubbström, 1998) (eur)

Table 2: Notation and the required data

## The economic relationships of the model

Items are assumed to have unit economic values, which could be different in different nodes. If in the case that the cargo becomes suddenly highly exposed to risk of decay and the smart devices recognise that, the system could report to near city, which hosts the child node, and smart city can organize the transactions for such cargo locally at lower but acceptable prices or, in the worst case, the city can organize the disposal of rotten goods. Therefore, we shall write the unperturbed price vector  $\mathbf{p}$  being a row vector:

$$\mathbf{p} = [p_1, p_2, \dots, p_n], \quad (6)$$

determined at the standard shelf life of the items  $RSL(k)$  in the nodes  $k, k = 1, 2, \dots, n$ , but in case of perturbations the prices could be lower than  $p_i$  or even negative if immediately a disposal is needed. Therefore, there exists a perturbed vector of lower prices:

$$\mathbf{p}^* = [p_1^*, p_2^*, \dots, p_n^*] \quad (7)$$

where  $p_k^* = p_k e^{-c(RSL(k) - RSL(k)^*)}$ . Following the procedure of Bogataj and Grubbström (2012, 2013) we can write the NPV of an perturbed CSC at constant  $\rho, NPV^*$ :

$$NPV^* = \mathbf{p}^* (\mathbf{I} - \tilde{\mathbf{H}}(\rho)) \tilde{\mathbf{P}}(\rho) - \mathbf{K} \tilde{\mathbf{v}}(\rho) \quad (8)$$

Here are ordering and other setup + fixed production costs per unit of activity appearing at each node, collected into the row and column vectors

$$\mathbf{K} = [K_1, K_2, \dots, K_n], \text{ and } \tilde{\mathbf{v}}(\rho) = \left[ \frac{e^{-\rho t_1} \hat{P}_1}{\rho T_1} \quad \dots \quad \frac{e^{-\rho t_n} \hat{P}_n}{\rho T_n} \right]^T \quad (9)$$

$\tilde{\mathbf{v}}(\rho)$  is giving proper timing (Bogataj and Grubbström, 2012) and  $\rho$  is continuous interest rate. To the net present value of activities in (9) we have to add also transportation costs, as developed in the paper Bogataj et al (2011), Bogataj and Bogataj (2001, 2007) and further explored in Bogataj and Grubbström (2012, 2013). Congestion which is increasing in national and international transportation networks remains a serious problem, influencing also  $\tilde{\tau}_{ij}$  matrix of time distances between nodes. It is known from many transportation studies that time spending distances gives better evaluation of transportation costs than Euclidian or road distances and therefore  $\tilde{\tau}_{ij}$  gives also better estimation on costs of transportation than just distance matrices ( see also Drobne et al, 2008; Usenik and Bogataj, 2005; ). Between location of activity cell  $i$  and following activity cell  $j$  transportation costs per item in transport could be determined by the product  $b_{ij} \tau_{ij}$  where  $b_{ij}$  presents transportation costs per item per time unit, which we collect into a transportation price matrix per unit of product transported so that NPV of transportation costs between activity cells are equal to:

$$NPV_{tr} = \mathbf{e} \begin{bmatrix} 0 & 0 & \dots & \dots & 0 \\ h_{2,1} b_{2,1} (\tau_{2,1}, \beta_{2,1}) \tau_{2,1} & 0 & \dots & \dots & 0 \\ \vdots & h_{3,2} b_{3,2} (\tau_{3,2}, \beta_{3,2}) \tau_{3,2} & 0 & \dots & 0 \\ \vdots & \vdots & \vdots & \dots & \vdots \\ h_{n,1} b_{n,1} (\tau_{n,1}, \beta_{n,1}) \tau_{n,1} & \dots & \dots & h_{n,n-1} b_{n,n-1} \tau_{n,n-1} & 0 \end{bmatrix} \tilde{\tau}(\rho) \mathbf{P}(\rho) \quad (10)$$

and  $\mathbf{e}$  is row vector of units (to summarize). Therefore the total Net Present Value  $NPV_{tot}$  in the flow is sum of all partial values:  $NPV_{tot} = NPV + NPV_{tr}$  in case that there is no perturbations and  $NPV_{tot}^* = NPV^* + NPV_{tr}^*$  in case of perturbations. The Cyber – Physical system captures the data in real time, process them and sends the proper warnings immediately to the decision makers involved.

## CASE STUDY

We undertook a case study in the meat industry in Italy. The company has six manufacturing plants in Italy, 1500 employees, 10 distribution platforms and over 550 million euros in revenue in 2014 (see figure 1, elaborated from Sgarbossa and Russo, 2017).

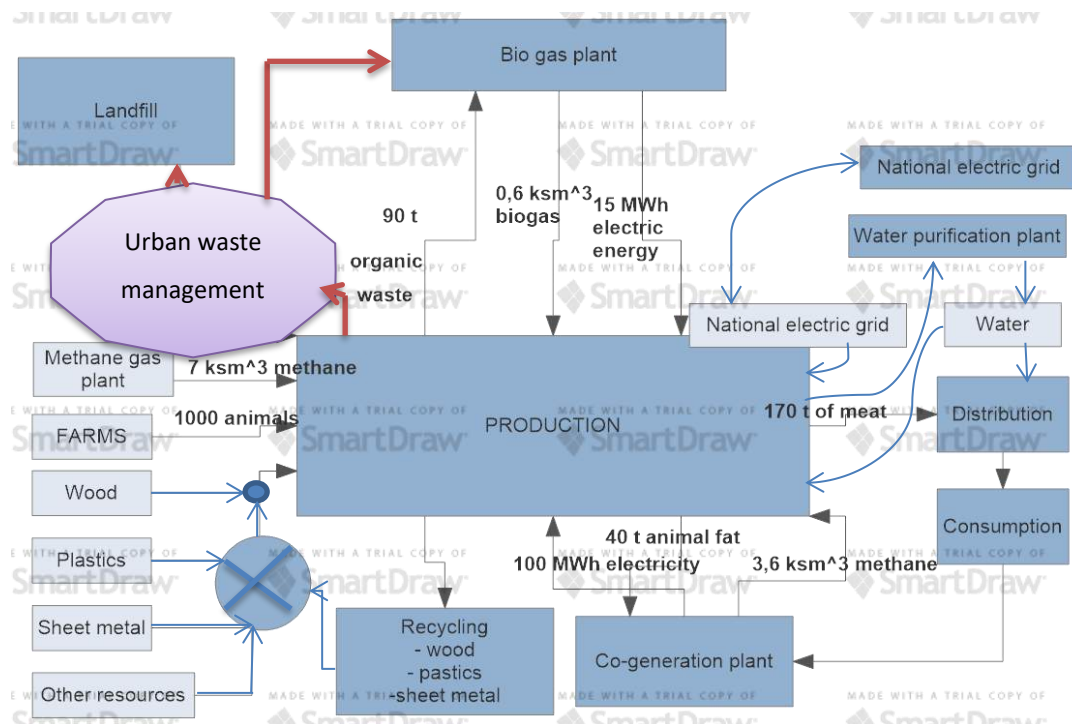


Figure 1: Daily production for the case study of the meat industry in Italy

We were collecting primary and secondary data. Semi-structured interviews with persons at managerial positions include also questions on specific information about the biogas and cogeneration plants and a list of possible slaughter wastes reused; this information provided insights that were extremely helpful in developing our economic evaluation based on the NPV approach, like investment cost for the plant, average number of animals, electric energy and methane gas as daily input, quantity of deboned meat animal fat, perishability dynamics and organic waste processed in average per day, also the relative production of electric and thermal energy. Based on the triangulation of data to verify the interviews and internal consistency the following secondary sources have been used: Eurostat; Processors and Poultry Trade (AVEC; [www.avec-poultry.eu](http://www.avec-poultry.eu)) in the EU and data of World Bank Group; (UNIPPEG; [www.unipeg.it](http://www.unipeg.it); 2014). The details see in Sgarbossa and Russo (2017). The daily inputs and outputs to the system is given in the figure 1. Based on the evaluation of (8),  $NPV_{tot}^* = NPV^* + NPV_{tr}^*$  could be calculated and in the case that  $\rho$  is constant and closed to 0.05 and perishability is known in advance, similar as in 2014, we are able to calculate the  $NPV_{tot}^*$  being close to  $11.27 \cdot 10^9$  EUR. Therefore the impact of changing perishability dynamics can be calculated when  $\mathbf{p}$  is replaced by  $\mathbf{p}^* = [p_1^*, p_2^*, \dots, p_n^*]$ , as explained in equation (7) where perishability and

timing are tied to the Bill of Materials. To be able to calculate  $NPV_{tot}$  and its changes regarding perturbations in a supply chain or changing the demand and plans, the data listed in table 2 should be recorded in real time and  $NPV_{tot}^*$  should be calculated in real time to be able to intervene when the results are falling below the determined margins. The procedures for evaluation of  $NPV_{tot}$  are explained in Bogataj, Grubbström (2012). By introducing perishability dynamics in the Bill of Materials and perishability costs in  $\mathbf{p}^*$  also sensitivity of the perturbed model can be analyzed in frequency domain and returned into the time domain in details.

## CONCLUSION

Development of Internet of Things as the infrastructure for Cyber-Physical Systems with embedded system technologies and distributed sensor network has enabled implementation of Extended MRP theory by allowing capturing time delays caused by perturbations in simple algebraic expressions. In this paper, we had attempted to show the needed procedures for evaluation of  $NPV$  and collection of data in the meat supply chain, if the highest possible  $NPV$  is the main goal of a management of close loop supply chain (CLSC), where Cyber-Physical System, based on the skeleton of extended MRP model, is used as a tool for management and control of production, distribution, consumption and reverse logistics. To evaluate also the influence of timing and financial consequences of perishability which appear in such chains,  $NPV$  approach as a measure of the economic performance is advised, showing that it is more suitable than cost approach. The combination of Input-Output Analysis and Laplace transforms enable an integrated analysis of the four sub-systems of manufacturing, distribution, consumption and reverse logistics. Here our analysis has been concentrated on the reverse logistics sub-system. We have attempted to show that these four sub-systems describing CLSC of meat production, distribution and reverse logistics may accurately be formalised using input and output matrices from MRP theory, when also transportation delays, perishability dynamics and transportation costs including costs of perishability are taken into consideration with the aid of transforms. The Net Present Value as a measure of the economic performance could be applied successfully when data are collected as given in the table 2. To the concept of CLSC developed in Bogataj and Grubbström (2012) the new concept of perishability dynamics is included. Using such approach to the collecting of data in meat industry also enable us to calculate the impact of an increasing time distance to the shelf-life of product, to the cogeneration plant and to disposal, to recycling, consequently influencing the resulting  $NPV$ . The environmental criteria can be additionally evaluated in multi - criterion approach in our future analysis.

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# A SUPPLY CHAIN MODEL WITH ENERGY CONSIDERATIONS FOR COLD CHAIN

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## ABSTRACT

**Purpose of this paper:** Reducing energy usage by a company lowers its operational costs and increases its competitive advantage. A coordinated approach to reduce energy usage across multiple stages in a supply chain is adopted. Such an approach is economically and environmentally better for the chain than firms acting unilaterally. Strategic decisions, e.g. configuring a supply chain system, significantly increase energy usage and subsequently operational costs.

**Design/methodology/approach:** This paper proposes a single-vendor and single-buyer production and inventory model that minimizes total costs including energy those from production (vendor) and warehousing (buyer) activities. It considers a situation where the amount of energy used is dependent on the speed (rate) of production. It also uses the sizes of the cold-storage facilities at warehouses (vendor and buyer) to calculate energy usage.

**Findings:** Numerical results demonstrate the efficiency of the solution considered compared to the traditional refrigeration technology involved in distribution chains.

**Value:** This paper advocates that energy is a key factor in making environmentally responsible lot sizing decisions. The higher the energy usage the less is the environmental performance of a system. Therefore, this paper addresses energy usage, as a key to sustainability, in production and inventory activities of a supply chain.

**Practical implications:** The model proposed in this paper has motivated by a real case study of a cold supply chain. In such chains, it is important to select the right coordination mechanism as it impacts the economic and environmental sustainability of a supply chain.

## 1 INTRODUCTION

Supply chain management (SCM) integrates business processes for the purpose of producing and delivering products, services and information of value to customers and stakeholders (Lambert, 2008). SCM is a key factor in enhancing supply chain profitability and responsiveness in a globalized and competitive market.

Having and maintaining successful coordination between a vendor and its buyer(s) is a primary managerial concern and a challenging research issue (Qin et al., 2007), which have caught the attention and interest of practitioners and academicians (Jaber and Zolfaghari, 2008; Toptal et al., 2003; Ertogral et al., 2007). The vendor-buyer coordination problem is referred to in the literature as the joint economic lot sizing (JELS) problem (e.g., Glock, 2012). The basic JELS model (Goyal, 1976) has been extended in many different directions to include "quality" (e.g. El Saadany et al., 2011, Glock et al., 2012), "controllable lead times" (e.g. Hoque and Goyal, 2000), "transportation" (e.g. Toptal et al., 2003; Ertogral et al., 2007) and other important factors (Jaber and Zolfaghari, 2008; Sajadieh and Jokar, 2009). Of particular interest to this paper is the work of Ertogral et al. (2007) who used a cost structure to calculate the transportation costs by considering transport vehicle capacity constraints. In this work, transport cost coefficients are



computed using the structure proposed by Ertogral et al. (2007) and parameterized by fuel (and refrigerant) consumption, which is influenced by weight and travel distance (see; Merrick and Bookbinder, 2010). Two alternative solutions are considered and compared in this paper by considering refrigerated transport-storage and the available technologies. The first involves trucks and units using vapour compression systems for refrigeration (STANDARD). The second is a new technology known as Portable Refrigerated Unit (PRU). This technology uses an active transportable insulated and refrigerated unit with an internal compressor that supplies the cargo space of any generic trailer not equipped for refrigerated goods transport by using a plug-in mechanism. With a PRU different classes of goods (refrigerated and non-refrigerated) can be shipped at the same time on the same truck, as no refrigerated equipment is necessary.

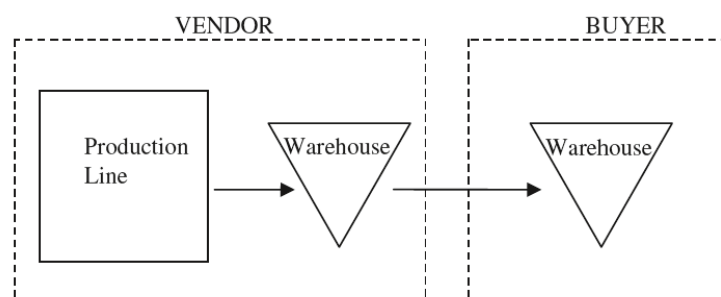
One of the motivations of this study focused on refrigerated goods is the fact that refrigeration, in general, affects both cost and environmental performance of food supply chain. An interesting study by James and James (2010) considered the effects of (1) climate change on the food chain and (2) food chain on climate change: this original double perspective underlines the need for the development of more efficient distribution systems for refrigerated goods.

This paper contributes to an emerging research trend that focuses on cold supply chains. It investigates a two-echelon supply chain model where the cost function, which is the sum of all costs (setup-order, holding, transport, and energy) for the vendor and the buyer, is minimized to determine the optimal production and shipping policies for two refrigeration technological solutions. In this regard, this paper extends the work of Zanoni et al. (2013) who studied the PRU solution as an economic and environmental advantageous option for cold supply chains.

The paper is organized as follows. In section 2 the vendor-buyer system is described, and main notation is offered. In section 3 the developed models for the two solutions (traditional vs. PRU solutions) are presented, while in section 4 numerical analysis are offered. Finally conclusions and future developments are summarized in the last section.

## 2 THE SYSTEM

This paper studies the system considered by Zanoni et al. (2012), illustrated in Fig. 1. It consists of a vendor and buyer with cold storage facilities at both locations. Energy consumption in production and storage activities influence the system variables, i.e. lot size, the number of shipment and the production rate.



**Fig. 1.** The system considered.

This study also considers the transport cost of refrigerated items; i.e., fish and related products. The cost components considered are:

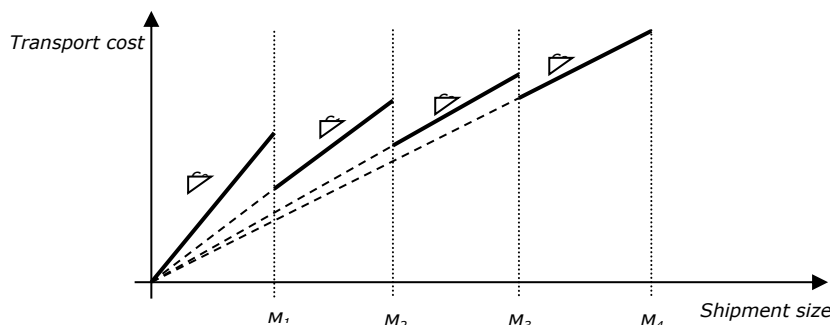
**Energy cost.** For the STANDARD solution, is the sum of energy consumption costs from production and storage. For PRU solution, energy cost includes energy consumption of PRU units employed in both transport and storage.

**Transport cost.** For the STANDARD solution, is the sum of costs of fuel that the trucks consume (to move the truck and refrigerate the storage) and refrigerant R134a used. For the PRU solution, it only includes the cost of fuel needed to move the truck; refrigerant R134a consumption is negligible.

In particular, the structure of the unit transportation cost is represented as follows:

$0 < q \leq M_1$	$c_0$
$M_1 < q \leq M_2$	$c_1$
...	...
$M_{k-1} < q \leq M_k$	$c_k$

where  $c_0 > c_1 > \dots > c_k$ . The following figure illustrates the costs structure when considering four different unit transportation cost.



**Fig. 2.** Transport cost structure.

## Notation

$A_1$	setup cost for Vendor (\$/lot)
$A_2$	order cost for Buyer (\$/shipment)
$h_1$	unit inventory holding cost for Vendor (\$/unit/year)
$h_2$	unit inventory holding cost for Buyer (\$/unit/year)
$p$	production rate (unit/year)
$d$	demand rate (unit/year)
$n$	number of shipments per production lot (shipment/lot)
$q$	shipment lot size (units/shipment)
$Q$	production lot size (units/lot) = $n \cdot q$
$q_{max,V}$	maximum level of stock at Vendor side (units)
$q_{max,B}$	maximum level of stock at Buyer side (units)
$e$	unit energy cost (\$/kWh)
$f_{cm}$	fuel consumption coeff. (motive) (l/km/t)
$f_{cr}$	fuel consumption coeff. (refriger.) (l/h)
$r_{cr}$	refrigerant R134a consumption coeff. (kg/truck/year)
$f_c$	fuel cost (\$/l)
$r_c$	refrigerant R134a cost (\$/kg)
$pp$	PRU electrical power (kW)
$tt$	total time (h/year)
$a, b$	coefficients that depend on production system features
$\alpha, \beta$	coefficients that depend on Vendor warehouse features
$\gamma, \delta$	coefficients that depend on Buyer warehouse features
$c_0, c_1, c_2$	unit transport cost (\$/unit)

$TrC$	traditional cost (\$/year)
$EC$	energy cost (\$/year)
$TranC$	transport cost (\$/year)
$TC$	total cost (\$/year)

As for single vendor-single buyer systems it is assumed  $p > d$ , i.e. production rate higher than demand rate; moreover stock-outs and shortages are not allowed.

### 3 MODEL

Two total cost functions are developed in the next subsections for STANDARD and PRU refrigeration storage, respectively.

#### 3.1 STANDARD solution

The cost function that includes the classic cost components, which are the setup-order and inventory costs for the Vendor and the Buyer, and it is written as:

$$TrC(q, n) = (A_1 + n \cdot A_2) \cdot \frac{d}{n \cdot q} + h_1 \cdot \left( \frac{d \cdot q}{p} + \frac{(p - d) \cdot n \cdot q}{2 \cdot p} \right) + (h_2 - h_1) \cdot \frac{q}{2} \quad (1)$$

where the lot size ( $q$ ) and the number of shipments ( $n$ ) are decision variables.

The energy cost components for the vendor's production process and the storage facilities at both locations (the Vendor ( $V$ ) and the Buyer ( $B$ )) are computed as per Zanoni et al. (2012). The specific energy consumption ( $SEC$ ) is a function of

- production rate
- Warehouses' features (mainly dimension: storage volume).

In particular, the following expressions are adopted to compute  $SEC$  and the energy consumption cost components, for (i) the production process, (ii) storage at Vendor's warehouse ( $Vw$ ), and (iii) storage at Buyer's warehouse ( $Bw$ ).

$$SEC_{vp} = a \cdot (p)^b \quad (2)$$

$$EC_{vp} = SEC_{vp} \cdot d \cdot e \quad (3)$$

$$SEC_{vw} = \alpha \cdot (q_{\max V})^{-\beta} \quad (4)$$

$$EC_{vw} = SEC_{vw} \cdot q_{\max V} \cdot e \quad (5)$$

$$SEC_{bw} = \gamma \cdot (q_{\max B})^{-\delta} \quad (6)$$

$$EC_{bw} = SEC_{bw} \cdot q_{\max B} \cdot e \quad (7)$$

The energy cost component that will be used in the cost functions is computed as follows:

$$EC = EC_{vp} + EC_{vw} + EC_{bw} \quad (8)$$

The transport cost component is computed considering the saturation value of the transport vehicle (related to cargo volume). In particular, a fixed saturation of the cargo volume is considered, so that a single truck can deliver a limited number of units; moreover, considering the total number of units to be delivered in each shipment and the number of units delivered by a single truck, the number of necessary trucks for each shipment can be computed. Fuel consumption depends on the distance travelled and load (weight) of the truck. Refrigeration cost depends on the time and the amount of refrigerant (R134a) consumed for each transported unit. The transport cost is computed as:

$$TranC = c_x \cdot d \quad (9)$$

where  $c_x$  (\$/unit) is the unit transport cost for a lot of size  $q$ , and it depends on the percentage of cargo volume saturation.

Total cost is the sum of traditional, energy and transport cost components.

$$TC = TrC + EC + TranC \quad (10)$$

The optimal value of total cost can be determined by optimizing values of  $q$ ,  $n$  and  $p$ , while the % saturation of transport vehicles is assumed as a given parameter. Since it is not possible to use the first order conditions to minimize Eq. (10) a numerical analysis is necessary to investigate the behaviour of the system.

### 3.2 PRU solution

The traditional cost function for the PRU storage technology is as expressed in Eq.(1).

The energy cost component to be added to Eq. (1) is computed in the same manner as has been done for the STANDARD solution using the SEC value as (see Eqs. (2)-(8)):

$$EC_{vp} = SEC_{vp} \cdot d \cdot e \quad (11)$$

The vendor's energy costs for the PRU solution is computed as:

$$EC_{VPRU} = z \cdot k \cdot e \cdot ecp_{filled} \quad (12)$$

where

$z$  : number of units/truck

$k$  : number of trucks/shipment

$e$  : unit energy cost (\$/kWh)

$ecp_{filled}$  : energy consumption of an PRU filled with goods is:

$$ecp_{filled} = pp \cdot tt \cdot \%lf \cdot \frac{d}{p} \quad (13)$$

where  $\%lf$  is the power load percentage when the PRU is filled,  $pp$  is the power consumed and  $tt$  is the time in storage.

The buyer's energy costs related is computed as:

$$EC_{BPRU} = z \cdot k \cdot e \cdot ecp_{empty} \quad (14)$$

where  $ecp_{empty}$  is the energy consumed when an PRU empty:

$$ecp_{empty} = pp \cdot tt \cdot \%le \cdot \left(1 - \frac{d}{p}\right) \quad (15)$$

with  $\%le$  representing the power load percentage when the PRU is empty.

Energy cost component is then computed as:

$$EC = EC_{vp} + EC_{VPRU} + EC_{BPRU} \quad (16)$$

The transport cost is computed as follows:

$$TranC = c_x \cdot d + c_{xR} \cdot x \quad (17)$$

where  $c_{xR}$  (\$/truck) is the unit transport cost for returning empty PRU units, and  $x$  is the number of trucks per year returning empty PRU units to Vendor's warehouse (see, Hariga et al., 2015).

Total cost function is the sum of the following cost components: traditional, energy and transport, and is given as:

$$TC = TrC + EC + TranC \quad (18)$$

Eq. (18) is minimized for the optimal of  $q$ ,  $n$  and  $p$ . The percentage of cargo saturation of the transport vehicles is an input parameter. Solving Eqs. (10) and (18) using differential calculus is not possible due to the complexity of the cost functions. Therefore, a numerical analysis is performed in the next section to investigate the behaviour of the system.

#### 4 NUMERICAL STUDY

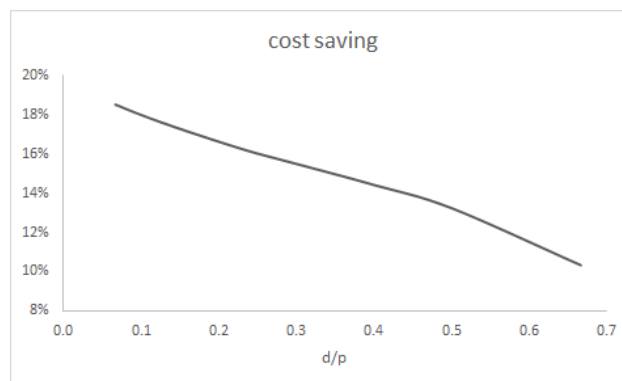
The numerical analysis is performed considering production, storage and transport of fresh fish (1 kg/unit, 300 units/m<sup>3</sup>, DEFRA, 2008). The values of the input parameters are presented in Table 2. Moreover, for transport activity 32-ton rigid trucks are considered: for STANDARD solution, a refrigeration system is necessary, so that 60 m<sup>3</sup> cargo volume is available; for PRU solution, no refrigeration system is necessary, and so a 66 m<sup>3</sup> cargo volume is considered. For both solutions 50% saturation of truck is considered; moreover, for the PRU solution also return travels are considered, to return PRU units to the Vendor: for this case a 100% saturation of vehicles is considered for empty PRUs return. The results of optimizing Eqs (10), STANDARD, and (18), PRU, are summarized in Table 3. The results show that using PRU trucks saves 17.37% a year (11,951.4 - 9,875.60 = 2,075.80 \$/year). Fig. 3 shows that savings reduce for increasing values of  $d/p$ .

**Table 2.** Data for numerical study.

$A_1$	2,000	\$/lot	$pp$	0.068	kW
$A_2$	400	\$/shipment	$tt$	8,640	h/year
$h_1$	0.1	\$/unit/year	$fc_m$	0.02083	l/km/t
$h_2$	0.15	\$/unit/year	$fcr$	2	l/h
$d$	20,000	units/year	$rcr$	0.003	kg/truck/year
$\alpha$	14.084	-	$fc$	1.3	\$/l
$\theta$	0.256	-	$e$	0.12	\$/kWh
$\gamma$	14.084	-	$rc$	9	\$/kg
$\delta$	0.256	-	% $lf$	100%	-
$a$	25.354	-	% $le$	120%	-
$b$	0.29	-			

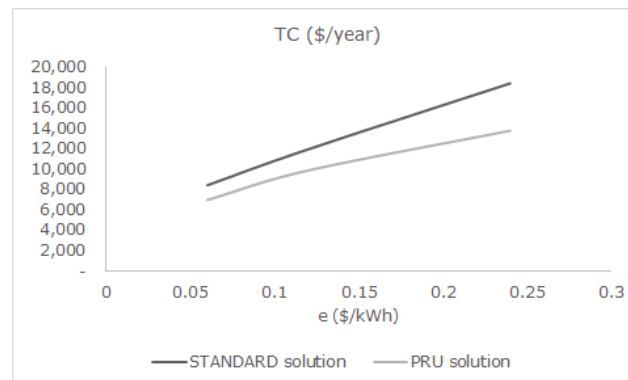
**Table 3.** Main results of numerical study: optimal solution results.

	$p$	$n$	$q$	$TrC$	$EC$	$TranC$	$TC$
<b>STANDARD solution</b>	30,000	4	5,000	4,391.67	6,641.32	918.41	11,951.4
<b>PRU solution</b>	20,000	20	5,000	2,625.00	5,793.25	1,457.34	9,875.60



**Fig. 3.** Optimal values of  $TC$  varying  $d/p$  value.

Moreover, the  $TC$  values for STANDARD and PRU solutions and the difference between them increase the unit energy cost (\$/kWh) increases.



**Fig. 4.** Optimal value of  $TC$  varying unit energy cost.

## 5 CONCLUSIONS

This paper studied the effects of energy consumption from production, transportation, and storage activities for a cold two-level supply chain. The models of this paper were inspired by a real case of a two-level (Vendor-Buyer) supply chain for seafood products. Two refrigerated vehicle-storage technologies were considered, i.e. STANDARD versus PRU trucks. Numerical results showed that the PRU solution performed better than the STANDARD solution with cost saving between 10% and 19% for different values of the ratio of demand to the production rate. PRU was shown to be cheaper to operate for higher unit energy cost. The energy cost significantly affects the economic sustainability of either technology. It accounts for 45-68% of total cost for the STANDARD solution and 42-48% for the PRU solution for a range of values of the unit energy cost (optimal solutions are considered). Further development of the present study could consider a supply chain structure where PRUs are portable containers with stochastic return times (see, Hariga et al., 2015). A future study will account for CO<sub>2</sub> emissions from using both technologies.

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# **COLD CHAIN BULLWHIP EFFECT: CAUSES AND MITIGATING MECHANISMS**

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### **Abstract**

**Purpose:** Information distortion amplifies order quantities during order delivery process across upstream supply chain in response to downstream sales information. Order quantity amplification known as 'bullwhip effect' during conventional order delivery process and the possible mitigating effects are well studied. However, it is not the same with respect to cold chains, characterized as time and temperature sensitive product supply chains, needs detail investigation. The purpose of this paper is to understand the causes of information distortion or bullwhip effect in the cold chains and propose suitable mitigating mechanisms.

**Design/methodology/approach:** Using hypothetical cold chain the study captures various attributes related to information distortion such as deterioration rate corresponding to product shelf life, status quo of information sharing and coordination. In terms of performance measure conventional product supply chains considers inventory on the other hand cold chains need to take into account the trade-off between inventory and waste. Hence, this study develops an optimization model to minimize overall cold chain cost including inventory and wastage cost with proper information sharing and coordination among members of cold chains.

**Findings:** The major causes of information distortion are capture of real time data and tracking, variation in seriousness among members of cold chain in sharing information, variation in tracing frequency among members, abuse of temperature and compliance. Few mitigating mechanisms are creating an aggregator to share cold storage space for suppliers, incentive for high quality, social media information to improve forecasting methods, transportation and storage costs based on energy consumption along with digitisation of cold chain member's process.



**Value:** The study is a first attempt to understand the causes of information distortion in cold chains and contributes to cold chain literature by analysing the characteristics of interaction between various pipeline members and their resultant impact on bullwhip effect. The paper provides a contextualisation of factors appertaining to bullwhip effect in cold supply chains and will be of equal value to practitioners and researchers.

**Research limitations/implications:** The study uses hypothetical data to verify the model but it would be realistic in future if one could capture the real time data. The real time temperature monitoring of cold chain will offer better predictor of shelf life and assessment of product waste by identifying potential areas of temperature excursions and remedial strategies.

**Practical implications:** The paper analyse the causes of inventory and waste due to bullwhip effect in cold chains. This would help in determining suitable counter measures and strategies for reducing bullwhip effect in cold chains. The information on sales data should be used in conjunction with shelf life information of products for efficient design of cold chains.

**Keywords:** cold chain, bullwhip effect, information distortion, coordination, mitigating mechanisms

## **Introduction**

Bullwhip effect is well studied phenomenon in conventional supply chains that demonstrates amplification of orders with variation in demand leading to accumulation of large amount of inventories (Lee et al., 2004). Inherent perishability of products in the cold chain leads to wastages in addition to accumulated inventory. The traceability systems are implemented by processing firms, but serves to increasingly benefit downstream distribution channels. This has led to use of traceability for regulating food safety and led to its failure as value-adding marketing tool (Mai et al., 2010). Unique identification and communication of data elements outside company of origin with internal traceability in production system will help in product differentiation and quality control (Donnelly et al., 2013). Data from monitoring systems should be used for prevention rather than inspection in the cold chain (Wang et al., 2013).

The research work focuses on reducing wastes, abuse of temperature and improving integrity in cold chain environment with coordinated effort on monitoring of information and traceability to maintain quality and further reduce wastes across the chain. The requirement for maintaining coordination is increasingly gaining importance on account of wastes and perishable nature of product. The deterioration of product is characterized with loss in quality and safety concerns upon final consumption by customers. The paper is structured and starts with the review of literature on causes of waste along with impact of information and coordination in cold chain. This is followed with problem description, formulation and analysis and results. The paper finally ends with a concluding remark for future work.

## **Literature review**

### **Causes of waste**

Around 40% of wastes originated during production, processing and distribution stages of food supply chains (Parfitt et al., 2010). Food waste is defined as "Wholesome edible material intended for human consumption, arising at any point in the food supply chain that is instead discarded, lost, degraded or consumed by pests" (Parfitt et al., 2010). Few causes of waste in different context are as follows: Poor logistics infrastructure, lack of cold storage and lack of packaging design, lack of integrated information technology (IT) systems and poor training in handling and stacking are causes of food wastes in the context of Indian perishable food supply chain (Balaji and Arshinder, 2016). Microbial

spoilage is another source of waste for short shelf life food supply chains (Joshi et al., 2012). Expiry dates are set at careful levels to account for uncertainties related to initial number of microbes and temperature during transport and storage. This might lead to disposal and wastes for products with remaining shelf life (Tromp et al., 2012). Storage environment and delivery time to customers influence food wastes during storage and transportation operations in cold chain (Zanoni and Zavanella, 2012; Shabani et al., 2012). Except infrastructure and cold storage other issues are more or less related to information and coordination.

### **Information and coordination**

Information asymmetry in the cold chain arises typically due to perishable nature of food products and requires accurate determination of expiry date, shelf life labels, uneven temperature distribution inside refrigerated vehicles and distinction of temperature for different products at different stages (Tromp et al., 2012; Aung and Chang, 2014; Shih and Wang, 2016; Ceuppens et al., 2016). Traceability systems are used for gathering information in the cold chain and its implementation is influenced by WTP (Willingness-To-Pay) a positive price by the customer (Ye et al., 2015; Wu et al., 2015).

Coordination leads to higher chain profit when price elasticity of demand is high and cost-sharing mechanism will lead to better trade-off for both parties (Yong-bo et al., 2008). Mahajan et al. (2013) evaluated supply chain performance for frozen corn manufacturing with coordination requirement in cold chain at various stages of network particularly during manufacturing, storage, transportation, retail and at consumers. Coordination would lower supply chain costs as compared to buyer's or vendor's perspective for a single-buyer and a single-vendor supply chain for deteriorating product with time varying demand and production rate synchronized with demand rate (Giri and Maiti, 2012). Mvumi et al. (2016) found that increase losses incurred at farming stage stemmed particularly during handling and transportation and causes were attributed with unreliable transport, poor communication and coordination between producers and processors along with inefficient temperature management and lack of sanitation.

### **Problem description**

The paper analyse the problem in a cold chain for perishable food products that undergo deterioration and leads to wastes. The problem imbibes causes of waste and suggests suitable curbing mitigating mechanism. The case considers causes of waste originating from uneven distribution of temperature inside refrigerated vehicles which creates challenge for preserving cold chain products (Aung and Chang, 2014). This waste is further transmitted downstream without coordination between different stages. The type of coordination mechanism in retailer-seller/producer-buyer transaction and travel time to milk suppliers are influenced by several factors ranging from location of producer, source of market information, distance to markets, travel time to buyers or suppliers, gender of operators and presence or absence of enforceable contracts (Abdulai and Birachi, 2009). The perishable product has a set of discrete deterioration states (A,B,C,D and E) with E being the expired state. Each of these states is transported in specialized refrigerated vehicles, having different refrigerated storage capacities at distribution and are sold at different price based on states (A is priced at \$600, B at \$500, C at \$400 and D at \$300). During transportation a deterioration state may downgrade to lower level based on transportation lead time between the stages (see Figure A1 in Appendix). For example deteriorated state A will transform to deteriorated state B if transportation lead time lies in the range (0.21, 0.28].

The problem addresses the mechanism for tackling issue of deterioration by coordination and information sharing to preserve flow in a synchronised manner for fulfilling customer demand. The model enables coordination by prohibiting the flow of deteriorated product states between subsequent stages by excluding the expired state E in order to maximize

the revenue. Figure 1 shows deterioration of product state between stages which occurs based on the distance between stages.

The cold chain is built and operated under following sets of assumptions:

1. Deterioration of perishable products is considered for discrete deterioration states (A, B, C, D, and E) with E being the expired product.
2. There will not be any deterioration during refrigerated storage at distribution.
3. There will be deterioration of perishable product state during transportation on basis of duration of travel time.
4. Flow of product is integer and infinite fleet of refrigerated transportation are available.

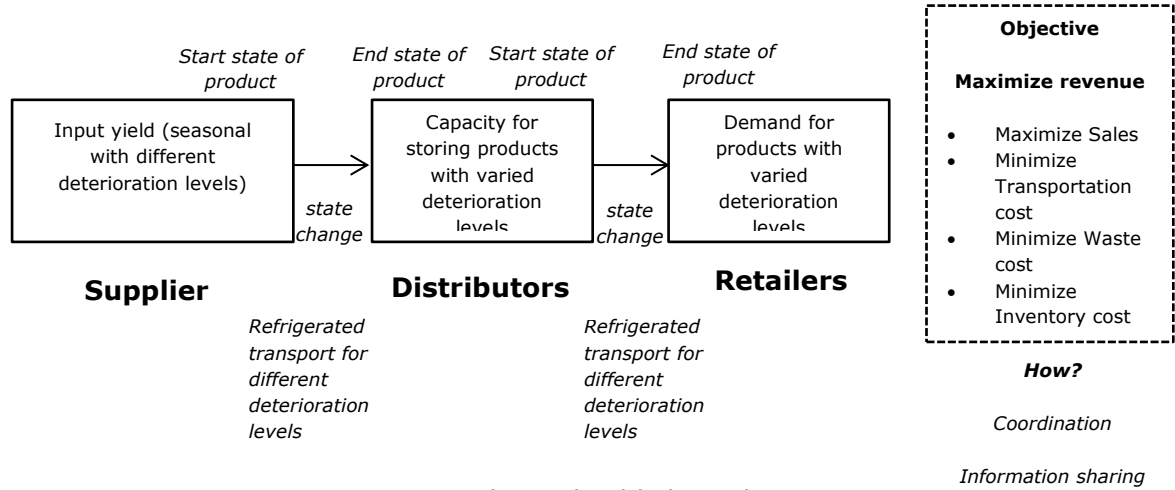


Figure 1: Coordinated cold chain design

## Problem Formulation

Set	Description and index
$S$	Set of $s$ suppliers, $i \in S$
$D$	Set of $d$ distributors, $j \in D$
$R$	Set of $r$ retailers, $k \in R$
$N$	Set of $n$ nodes, $N = S \cup D \cup R$
$C$	Set of $p$ product deterioration states, $c \in C$
$C'$	Set of product deterioration states excluding expired state, $c \in C - \{E\}$
$C_{cnm}$	Set of product states with less deterioration level than state $c$ determined based on lane distance from $n$ to $m$ , $C_{cnm} \subseteq C, \forall c \in C, n \in N, m \in N, n \neq m$
$T$	Set of $p$ time periods, $t \in T$

Table 1: Sets and indices

Notation	Description
$TC_{ijc}$	Transportation cost from supplier ( $i$ ) to distributor ( $j$ ) for product state ( $c$ ), $i \in S, j \in D, c \in C$
$TC_{jkc}$	Transportation cost from distributor ( $j$ ) to retailer ( $k$ ) for product state ( $c$ ), $j \in D, k \in R, c \in C$
$WC$	Waste cost at supplier
$EC$	Expired product cost
$HC_c$	Inventory holding cost for product state ( $c$ ), $c \in C$
$Price_c$	Selling price for product state ( $c$ ), $c \in C$

Notation	Description
$I_{itc}$	Input yield for supplier (i) at time (t) for product state (c), $i \in S, t \in T, c \in C'$
$Cap_{jc}$	Capacity at distributor (j) for product state (c), $j \in D, c \in C'$
$Dem_{ktc}$	Demand at retailer (k) for product state (c), $k \in R, t \in T, c \in C'$

Table 2: Input parameters

Notation	Description
$x_{ijtc}^s$	Integer flow from supplier (i) to distributor (j) at time (t) with start product state (c), $i \in S, j \in D, t \in T, c \in C$
$x_{ijtc}^e$	Integer flow from supplier (i) to distributor (j) at time (t) with end product state (c), $i \in S, j \in D, t \in T, c \in C$
$y_{ijtc}^s$	Integer flow from distributor (j) to retailer (k) at time (t) with start product state (c), $i \in S, j \in D, t \in T, c \in C$
$y_{ijtc}^e$	Integer flow from distributor (j) to retailer (k) at time (t) with end product state (c), $i \in S, j \in D, t \in T, c \in C$
$Inv_{jtc}$	Inventory with distributor (j) at time (t) for product state (c), $j \in D, t \in T, c \in C'$
$SSl_{itc}$	Supply slack at supplier (i) for product state (c), $i \in S, t \in T, c \in C'$
$DSl_{ktc}$	Demand slack at retailer (k) for product state (c), $k \in R, t \in T, c \in C'$

Table 3: Decision variables

Maximize:

$$\begin{aligned} & \sum_{j \in D} \sum_{k \in R} \sum_{t \in T} \sum_{c \in C'} \left( y_{jktc}^e \times Price_c \right) - \sum_{i \in S} \sum_{j \in D} \sum_{t \in T} \sum_{c \in C'} \left( x_{ijtc}^s \times TC_{ijc} \right) - \sum_{j \in D} \sum_{k \in R} \sum_{t \in T} \sum_{c \in C'} \left( y_{jktc}^s \times TC_{jkc} \right) - \\ & \sum_{i \in S} \sum_{t \in T} \sum_{c \in C'} \left( SSl_{itc} \times WC \right) - \sum_{i \in S} \sum_{j \in D} \sum_{t \in T} \sum_{c \in \{E'\}} \left( x_{ijtc}^e \times EC \right) - \sum_{j \in D} \sum_{k \in R} \sum_{t \in T} \sum_{c \in \{E'\}} \left( y_{jktc}^e \times EC \right) - \sum_{j \in D} \sum_{t \in T} \sum_{c \in C'} \left( Inv_{jtc} \times HC_c \right) \end{aligned} \quad (1)$$

subject to

$$x_{ijtc}^s + SSl_{itc} = I_{itc}, \forall i \in S, t \in T, c \in C' \quad (2)$$

$$x_{ijtc}^s = x_{ijts}^e, \forall i \in S, j \in D, t \in T, c \in C, s \in C \quad (2-a)$$

$$x_{ijtc}^s = x_{ijts}^e, \forall i \in S, j \in D, t \in T, c \in C, s \in C_{cij} \quad (2-b)$$

$$x_{ijtc}^s = 0, \forall i \in S, j \in D, t \in T, c = \{E'\} \quad (3)$$

$$x_{ijtc}^e = 0, \forall i \in S, j \in D, t \in T, c = \{E'\} \quad (4)$$

$$\sum_{c \in C} x_{ijtc}^s = \sum_{c \in C} x_{ijtc}^e, \forall i \in S, j \in D, t \in T \quad (5)$$

$$\sum_{s \in C_c} x_{ijts}^s \geq x_{ijtc}^e, \forall i \in S, j \in D, t \in T, c \in C \quad (6)$$

$$\sum_{i \in S} x_{ijtc}^e + Inv_{j(t-1)c} = Inv_{jtc} + \sum_{k \in R} y_{jktc}^s, \forall j \in D, t \in T, c \in C' \quad (7)$$

$$Inv_{jtc} \leq \sum_{k \in R} Cap_{jc}, \forall j \in D, t \in T, c \in C' \quad (8)$$

$$\sum_{i \in S} x_{ijtc}^e = \sum_{k \in R} y_{jktc}^s, \forall j \in D, t \in T, c = \{E'\} \quad (9)$$

$$y_{jktc}^s = y_{jktc}^e, \forall j \in D, k \in R, t \in T, c \in C, s \in C \quad (10 - a)$$

$$y_{jktc}^s = y_{jktc}^e, \forall j \in D, k \in R, t \in T, c \in C, s \in C_{cjk} \quad (10 - b)$$

$$y_{jktc}^s = 0, \forall j \in D, k \in R, t \in T, c = \{ 'E' \} \quad (11)$$

$$y_{jktc}^e = 0, \forall j \in D, k \in R, t \in T, c = \{ 'E' \} \quad (12)$$

$$\sum_{c \in C} y_{jktc}^s = \sum_{c \in C} y_{jktc}^e, \forall j \in D, k \in R, t \in T \quad (13)$$

$$\sum_{s \in C_c} y_{jktc}^s \geq y_{jktc}^e, \forall i \in S, j \in D, t \in T, c \in C \quad (14)$$

$$\sum_{j \in D} y_{jktc}^e + DSL_{ktc} = Dem_{ktc}, \forall k \in R, t \in T, c \in C' \quad (15)$$

Expression (1) denotes objective function comprising of maximizing revenue for coordinated scenario while it focuses on maximizing sales for base case. The cost components for coordinated scenario comprises of refrigerated transportation cost for different deteriorated products (in this case A,B,C and D), waste cost at supplier, distributor and retailer along with inventory holding cost at distributor. Equation (2) is supplier flow constraint, equation (2-a) and equation (2-b) are state change constraints for base and coordinated scenarios for upstream flow. Equations 3 and 4 prohibit the movement of expired products from supplier to distributor. Equation (5) ensures the change in product state to be fixed upon deterioration while inequality (6) ensures product deterioration to lower levels only for upstream flow. Equation (7) is inventory balance constraint and inequality (8) is capacity constraint at distributor. Equation (9) balances flow of expired product for distributor. Equation (10-a) and equation (10-b) are state change constraints for base and coordinated scenarios for downstream flow. Equations 11 and 12 prohibit the movement of expired products from distributor to retailer. Equation (13) ensures the change in product state to be fixed upon deterioration while inequality (14) ensures product deterioration to lower levels only for downstream flow. Equation (15) is demand satisfaction constraint.

## Illustration and Results

The cold chain under consideration consists of five time periods in a three echelon network which comprises of three suppliers, two distributors and a retailer. The product deterioration consists of five discrete states with E denoting expired state. The input yield is seasonal with high supply in first two months while demand is relatively stable. Base scenario without coordination is solved for maximizing sales without cost and constraints 2, (2-a), 5-9, (10-a), 13-15. Coordinated scenario is solved for maximizing revenue and constraints 2, (2-b), 3-9, (10-b), 11-15. Performance of cold chain under base and coordinated scenarios is illustrated in Table 4. The performance of base scenario is negative by considering wastages and higher lost sales, which is improved reasonably upon coordination. All input tables are shown in Appendix.

A deep analysis into cost comparison for base and coordinated scenarios reveals several important insights. The analysis depicts that there is significant reduction in waste at all stages due to coordination. However, the transportation and inventory costs are higher for coordinated scenario which seems right as distribution stocks and moves products requiring refrigerated storage and transportation. The right state product having different prices based on deterioration levels are sold to retailer generating higher revenues. Large amount of products gets wasted during upstream stages for base scenario results in lost sales from unmet demand. This clearly depicts positive impact of coordination on performance of cold chain.

## Concluding remarks

Paper analyses cold chain for perishable product with discrete states of deterioration. The result illustrates increasing benefits of coordination in cold chain. Bullwhip effect in conventional supply chain is caused by demand visibility, order batching, fluctuating prices and supply shortage (Lee et al., 2004). The shelf life of perishable product imposes additional constraint requiring the chain to pull product at a rate that fulfils product demand while also minimizing the wastes. The study has demonstrated impact of coordination and information sharing which consequently leads to low wastages. Around 40% of wastes originated during production, processing and distribution stages in food supply chains (Parfitt et al., 2010). The result from study confirms findings from previous studies. Sourcing of perishable product based on shelf life reduces product waste, but will increase transportation cost (Rijpkema et al., 2014). The demand forecasting for agri-fresh products should be done at disaggregate levels by considering seasonality and perishability (Shukla and Jharkharia, 2013).

Performance Measure	Base Scenario	Coordinated Scenario
<b>Total Sales</b>	<b>\$586,100</b>	<b>\$789,800</b>
Supplier waste cost	\$52,150	\$25,650
Distributor waste cost	\$25,700	\$0
Retailer waste cost	\$25,700	\$0
Upstream transportation cost	\$142,663	\$161,484
Downstream transportation cost	\$128,645	\$149,782
Inventory cost	\$22,500	\$31,245
Lost sales (Unmet Demand)	\$203,700	\$0
<b>Total Cost</b>	<b>\$601,058</b>	<b>\$368,161</b>
<b>Revenue (Total Sales - Total Cost)</b>	<b>-\$14,958</b>	<b>\$421,639</b>

Table 4: Performance of cold chain under base and coordinated scenarios

The study demonstrates several causes of food wastages such as lack of supply infrastructure at upstream, inadequate testing mechanism for sourcing between different stages and temperature abuse during transportation. We suggest using traceability and information systems for building coordination and improving performance of cold chain for reducing wastage to downstream stages. This would prohibit transfer of expired product to downstream channels for fulfilment of demand. Usage of RFID can help in detecting shelf life of perishable food products to supplant expiry date (Grunow and Piramuthu, 2013). Requirement driven approach for packaging design based on physiological needs transforms product requirement into packaging properties prior to package designing. This is particularly useful for reducing the risks between packaging and produce (Cagnon et al., 2013; Pagani et al., 2015). The delivery time and environmental conditions are the necessary factors that influence deterioration rate for perishable. In such cases, social media information can be used to improve the forecasting methods. Also, there exist higher incentives for providing products with low level of product deterioration. The study can be extended by including uncertainty in demand, continuous change in product deterioration during storage and subsequent batching based on clustering of perishable product categories.

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## **Session 10: Sustainability in Logistics and Supply Chains**

# **SUPPLIER RELATIONSHIP MANAGEMENT IN A CIRCULAR ECONOMY: CORE BROKERS IN AUTOMOTIVE REMANUFACTURING**

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## **Abstract**

**Purpose of this paper:** In a circular economy, remanufacturing can be a contribution to sustainability objectives such as described by the triple bottom line. Market experts from automotive remanufacturing rather identify supply of cores (used products) than the demand of remanufactured products as an issue for the industry. Due to a growing variety of car components, it becomes increasingly difficult to handle according data that identifies the correct components. Middleman, i.e. core brokers, play a crucial role in consolidating cores in the independent reverse supply chain (SC). Amongst the challenges in this SC are supply uncertainties, the bargaining power of dismantlers and lead-times. Therefore, this paper seeks to answer the question how core brokers and dismantlers in the remanufacturing SC implement supplier relationship management in order to address these challenges.

**Design/methodology/approach:** The study follows an inductive-deductive approach with elements of grounded theory in order to address knowledge gaps regarding supplier relationships management (SRM) implementation in independent automotive remanufacturing. The approach supports the comparison of market regions and the integration of a variety of market actors. The theoretical background from SRM and related theories from new institutional economics provide the reference for analysis and discussion. The field research comprises Europe and North America with 7 key informants and 23 interviews (n = 30).

**Findings:** Findings indicate that the procurement process between core brokers and dismantlers in Europe is mainly document-based. In contrast, the research identifies e-procurement solutions for core broking between dismantlers and core brokers in North America. These solutions contribute to an increased transparency as well as to the simplicity of logistics processes by integrating complex data on parts variety and interchangeability. Uncertainties, information asymmetries and further transaction costs explain the development of organisational relationships between markets and hierarchies in accordance with theory.

**Research limitations/implications:** The study does not assess the sustainability of parts remanufacturing itself. Despite a wide range of represented market actors in the study group, the study provides only limited information directly collected from both European core brokers and dismantlers. However, selected key informants and dismantlers in Europe are already considered to complement the research data.

**Practical implications:** Reduction of information and transaction costs, reduced lead-times and fewer intermediaries, are crucial for the independent remanufacturing SC in order to oppose more integrated closed-loop SCs efficiently. E-procurement tools that take the particular challenges of parts variety and interchangeability into account can support the circular flow of used products into remanufacturing and into reuse in general. The basic idea of the identified solution, adopted to other industries, could serve reuse and remanufacturing supply in general.

**Value:** The paper adds to the body of knowledge on relationships in automotive remanufacturing. Therein, it focusses on forward SCs and addresses a gap regarding the role and

potential of middleman who connect recyclers and dismantlers through 'buy-back' relationships with the remanufacturing industry.

## INTRODUCTION

The circular economy is a driving force in a sustainability-oriented industry environment. The awareness for environmental impacts and growing material demand (EC, 2015) persuade industries to seek for alternatives to linear business models. Accordingly, businesses shift their focus towards sustainability objectives such as described by the triple bottom line (Elkington, 1994). One contribution to sustainability can be the reuse of products due to the residual value hence the potential to conserve resources (Thierry *et al.*, 1995), which *ceteris paribus* lowers environmental impacts. Remanufacturing as one circular economy strategy experiences a growing interest from industry and policy alike (EC, 2015; Ellen MacArthur Foundation, 2013), *inter alia*, due to the business case of additional value-added lifecycles, and due its regional demand for labour. Despite positive market projections, the automotive remanufacturing industry claims supply and transparency issues (Weiland, 2012). Experts rather identify supply of cores as an issue than the demand for remanufactured products (Steinhilper, 2012; own research). Cores are used components and the key commodity for remanufacturing. The increasing variety of new components challenges the remanufacturing Supply Chain (SC). Increasing data on component variety hampers the identification of correct cores. Therefore, middleman, so called core brokers, play a crucial role in consolidating cores in the independent reverse SC for remanufacturing. Core brokers deal with cores, which they acquire mainly at vehicle dismantlers, and they distribute cores to remanufacturers. Through a manufacturing-like process, remanufacturers turn these cores into components (spare parts) of a quality comparable with original new components.

A brief analysis of the market regarding the core broker following Porter's (2008) 'five forces' model of competitive rivalry shall help to understand the importance of supplier relations between core brokers and their suppliers. The most important threats for core brokers stem from the bargaining power of dismantlers and from substitutes. Dismantlers have different sales options besides remanufacturing, mainly material recycling, and the costs of part dismantling can challenge their profit margin. If remanufactures fail in their key challenge of coordinating supply and demand, substitutes in the form of part copies may reach the market earlier than remanufactured parts. The copied part substitutes the remanufactured part hence indirectly substitutes the core broker's key commodity. The threat of substitutes extends to the bargaining power of the customers, i.e. the remanufacturers, who, by far, represent the predominant distribution channel for core brokers. Especially labour and resource costs drive remanufacturing profitability. Therefore, the core price is a major factor for the profitability of remanufacturing. The market forces due to the threat of entry are relatively low, because core brokers need to establish relations to a high number of dismantlers and must develop a deep understanding of cores and their demand patterns. According to market experts, the rivalry between core brokers is relatively high, which already reduced their total number.

Identifying reasons and potential solutions for these challenges motivates this research. Improving core supply may increase the potential contribution of remanufacturing to the triple bottom line. Especially important are supply uncertainties and risks due to the bargaining power of dismantlers and the core supply lead-time. Therefore, the driving research questions is how independent actors in the remanufacturing SC implement supplier relationship management. A focus is on core brokers and dismantlers. The study leads to implications for independent reverse supply channels in remanufacturing.

## LITERATURE

### Forward and Closed-Loop Supply Chains for Remanufacturing

Businesses dedicated to remanufacturing are facing procurement challenges in order to 'close the loop' from the End-of-Life of a product to the doorstep of their production (Östlin *et al.*, 2008). Businesses address these challenges with integration, i.e. closed-loop SCs, and incentives in order to increase the reverse flow of used products. Whether forward or

closed-loop SCs, the core acquisition and the physical return adds complexity to SC management, e.g. in face of supply and demand balancing (Daniel *et al.*, 2000). Businesses and SCs that intend to close the loop face issues such as the identification of sources of cores (Guide and van Wassenhove, 2008) or operational issues in reverse logistics and lead-time (Östlin *et al.*, 2008). Although remanufacturers regularly use deposits to facilitate the reverse flow of cores (Östlin *et al.*, 2008), they further relate to core brokers for additional supply (Sundin and Dunbäck, 2013). Especially closed-loop SCs tend to avoid the transfer of ownership in order to increase product returns (Thierry *et al.*, 1995).

Literature on remanufacturing SCs mainly focuses on normative research (Prahinski and Kocabasoglu, 2006; Guide and van Wassenhove, 2008), operative aspects regarding system design (Jayaraman *et al.*, 2003), or ownership issues influencing material flows (Hagelüken, 2007). Many operational models apply assumptions such as perfect substitution, which are difficult to map with the real world (Guide and van Wassenhove, 2008). Östlin *et al.* (2008) mention the relationships in context of reverse SCs. However, literature hardly focuses on the role of middleman, such as brokers and agencies (Prahinski and Kocabasoglu, 2006). As long as dismantlers are market organizations, the role of core brokers as middleman remains crucial for the SC of cores.

### **Management of Supplier Relationships**

SC literature conceptualizes relations by the perspectives of relationship marketing (Christopher *et al.*, 2002) or supplier relationships (Sheth and Sharma, 1997). Similar as in sales relations, companies use incentives in procurement relations in order to achieve the own objectives (Biergans, 1984). For remanufacturing, such objectives could be pre-emption of cores or reduction of lead-times. Relationship marketing is one approach to reduce costs and risks by establishing 'collaborative relations' between legally independent businesses in order to secure production. Maintaining relationships with transaction partners is essential to ensure return flows of cores (Subramoniam *et al.*, 2010). Östlin *et al.* (2008) and Lind *et al.* (2014) identify the variety of relationships in reverse logistics for remanufacturing, namely ownership-based, service contract, direct-order, deposit-based, credit-based, buy-back, voluntary-based, and reman-contract. Drawing on these relationships, Sundin and Dunbäck (2013) analyse challenges in automotive remanufacturing. They consider the typical 'buy-back' relation between core brokers and their suppliers a "lack of relationship". For this study, supplier relations are relevant due to the challenging management of used-product returns in the complex trade-off between time, cost and quality.

The demand for an improved management of complex supplier relations encouraged the development of IT support for procurement processes, subsumed under the term Supplier Relationship Management (SRM) (Herrmann and Hodgson, 2001). The automotive industry can be considered a pioneer in terms of SCM, and the application of according SRM tools (Appelfeller and Buchholz, 2011). Solutions that aim to improve the management of supplier relations are particularly relevant in an industry where successful procurement becomes a competitive advantage (Herrmann and Hodgson, 2001). Despite evidence for sophisticated SRM in the automotive industry, there is limited evidence of such in independent automotive remanufacturing. Amongst the few examples are CoremanNET, a logistics solution that supports the core return management ([www.coremannet.com](http://www.coremannet.com)), focussing on deposit-based relationships; and LevelSeven, a Microsoft Dynamics based remanufacturing solution ([www.lvlsvn.com](http://www.lvlsvn.com)). To the author's understanding, these and other solutions do not attach significance to buy-back relations with core brokers. Due to complex reverse logistics, especially in forward SCs with less vertical integration than in closed-loop SCs, the lack of SRM-tools gives reason to investigate this gap.

### **Reference to New Institutional Economics**

The objective of SRM is to reduce cost related to the management of supplier relations and to achieve the company's supply objectives (serving the primary business strategy). New institutional economics are assumed to provide a useful set of theories to approach the organisational aspects from an economic perspective (Hobbs, 1996). Theory provides, for

example, the concept of transaction costs, the principal agent problem (Richter and Furubotn, 2010) and property rights (Alchian and Demsetz, 1972). These theories can help to explain why there is more or less organisational integration in the core-supply market channels. For example, the transfer of ownership is a challenge for reverse logistics therefore deposits serve as incentives (Thierry *et al.*, 1995; Wei *et al.*, 2014). Furthermore, uncertainties such as quality or time, combined with resource dependence and transaction costs motivates vertical integration in order to reduce associated risks (Williamson, 1975; Salancik and Pfeffer, 1977; Carter and Rogers, 2008; Subramoniam *et al.*, 2010). In addition, relationships can support the establishment of organisations ranging between markets and hierarchies (Hougaard and Bjerre, 2002, pp. 60ff). The implementation of SRM tools indicates a move towards such organisation between market and hierarchy.

## **METHOD AND STUDY GROUP**

This study follows an inductive-deductive approach with elements of grounded theory in order to address knowledge gaps regarding SRM implementation in independent automotive remanufacturing. Grounded theory helps to build a macro-image of the study ground. Examples for the application of grounded theory in the fields of SC and sustainability management are, for example, Carter and Dresner (2001) and Crook and Kumar (1998). The “planned but flexible” approach of grounded theory allows constantly revising and adjusting previous assumptions (Glaser, 2007). This study follows this approach, with the ultimate purpose to unfold practical benefits (Crook and Kumar, 1998). The approach supports the comparison of market regions. It allows revising and reflecting initial findings from one region against literature as well as against the findings from another region. The explorative nature of the chosen approach supports the integration of a variety of market actors.

The field research comprises Europe (4 North-Western European and 1 Eastern European country) and North America (USA and Canada). The industry exhibitions and conferences at ReMaTec 2015 in Amsterdam, Netherlands, and at BigR/ReMaTec 2017 in Las Vegas, NV, U.S., provide a broader overview of the according remanufacturing markets. Interviews and key informants of different background in the remanufacturing market in Europe and North America complement the field research. Table 1 shows the number of interviews and key informants; the elements are grouped due to the study objective to create a macro image of the study ground and due to anonymization requirements. Study data was collected in Europe (EU) from subject groups A-H and from groups I-N in North America (NA). Due to anonymization, some information is intentionally excluded or abstracted, too. Findings that originate from particular sources are highlighted in more detail in the results section. Original Equipment (OE) dependency describes the integration into OE Suppliers (i.e. first tiers) or OE Manufacturers. An in-depth literature research preceded the field research. Follow-up literature reviews as well as document studies, including research on relevant e-procurement and SRM solutions, complement the research and data acquisition phase. The information retrieved from interviews and key informants was clustered and analysed per the study focus on supplier relations (such as supply and procurement channels, types of relations, use of deposits, particular supply issues in independent channels, procurement processes and tools).

The study comprises of 7 key informants and 23 interviews (n = 30). The nine identified categories for the research subjects are Core Broker; Remanufacturer/Wholesaler; Remanufacturer; First-Tier Supplier (with) Remanufacturing; Remanufacturer Supplier; Remanufacturing Software Providers; Dismantlers; Auto Recycling Expert; and Market Expert. The data acquisition as well as the relation of company locations are equally distributed between Europe and North America (15:15). Despite this equal distribution, some of the locations of data acquisition are vice versa to the subject’s regular locations. Differences exist between the compositions of regional data sources. While the overall focus is on independent companies or experts, the two OE-integrated organizations are European. Furthermore, there are more core brokers from North America than Europe in the study group. Notably, dismantlers were only studied in North America. Especially core brokers in Europe allowed only limited insights. This reluctance of middleman in Europe to discuss

procurement practises may be related to findings from Medina (2015) who investigated the role of middleman in formal and informal scavenging; core brokers are middleman connecting dismantlers (of a historically/partly informal sector) with the (formal) remanufacturing sector.

Key Inform.* / Inter-views (grouped)	Company category	Dependency on OE	Company Location(s) (EU : NA)	Date (Place)
<b>A*</b>	Remanufacturer / Wholesaler	Indep.	1:0	Oct. 2014 (EU)
<b>B*</b>	Reman. Supplier	Indep.	1:0	Sep. 2015 (EU)
<b>C*</b>	Remanufacturer	Indep.	1:0	Sep. 2015 (EU)
<b>D</b>	Core Broker	Indep.	3:1	June 2015 (EU)
<b>E</b>	First tier supplier remanufacturing	OE-integrated	2:0	
<b>F</b>	Remanufacturer	Indep.	3:1	
<b>G</b>	Reman. Supplier	Indep.	1:0	<i>ReMaTec, Amsterdam, Netherlands</i>
<b>H</b>	"Market Expert"	Indep.	1:0	
<b>I*</b>	"Auto Recycling Expert"	Indep.	0:1	Sep. 2016 (NA)
<b>J*</b>	Dismantler	Indep.	0:3	Nov. 2016 (NA)
<b>K</b>	Core broker	Indep.	0:6	Oct. 2016 (NA)
<b>L</b>	Reman. Software	Indep.	2:1	<i>BigR, Las Vegas, NV, US</i>
<b>M</b>	Remanufacturer	Indep.	0:1	
<b>N</b>	"market expert"	Indep.	0:1	
<i>n=30</i>		28:2	15:15	

Table 1: Study data details, grouped by company category and place of data acquisition

## RESULTS

The research initiated from supplier relations in independent remanufacturing. Subsequently, the identified differences between Europe and North America gave rise the study of e-procurement. Although field research in Europe did not cover in detail the relation between dismantlers and core brokers, findings indicate that the procurement process is mainly document-based. The transaction partners use phone calls and excel sheets circulated via e-mail to negotiate transaction details (key informant A). Core brokers' and software providers' public web resources did not show any notable differences and support the impression of a generally document-based core broking process across Europe. A closer examination of European software for dismantlers reveals solutions that cover distribution channels towards platforms such as eBay (for example, [www.kaputt-gmbh.de](http://www.kaputt-gmbh.de), [www.call-parts-recycling.de](http://www.call-parts-recycling.de), [www.software-kern.eu](http://www.software-kern.eu)). Although some offerings mention connections to 'other platforms', they are missing explicit e-procurement interfaces for the connection with core brokers. In contrast, the field research in North America as well as the revision of web sources and of software offerings for dismantlers clearly identifies e-procurement approaches for core broking between dismantlers and core brokers in North America. Some core brokers (out of group K) offer vehicle dismantlers (group J) e-procurement interfaces to receive quotes for cores and to manage according transactions. Other core brokers, who do not use e-procurement, still rely on personal and long-term relationships, which they built up with smaller core brokers and dismantlers (group K). Figure 1 shows a simplified demonstration of the e-procurement solution explained in the following.

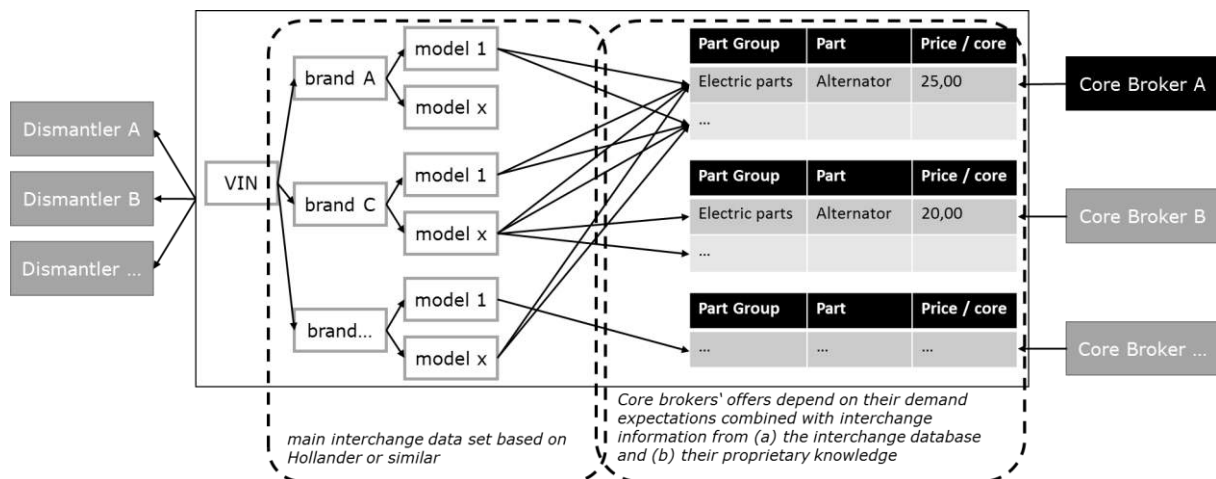


Fig. 1: Core Broking e-procurement solution with VIN-resolution

The identified e-procurement solutions are the crucial value-added feature in the supplier relations. This feature identifies for the dismantlers those components a core broker is interested in based on the individual vehicle. A current challenge for independent actors in the reverse SC for automotive remanufacturing is the complexity of modern vehicles in terms of the amount and variety of components and the corresponding component numbers. OEMs may have assembled different components within a particular model or even model year, or component numbers changed; though it remains unclear whether the component has physically changed or only its number (A, C, J, and K). This development increases the amount of data dismantlers and core brokers must deal with in order to identify the correct cores from a vehicle. Furthermore, the accordingly increasing component variety and vehicle-to-components mapping is OEM knowledge and not fully covered by part and component databases (e.g. TecDoc, Hollander interchange, Mitchel), especially not those components that would be interchangeable between models and makes. The interchangeability is most relevant, though databases seem to have their limitations (core broker from group K). Therefore, dismantlers must rely on their experience when they decide to dismantle cores. Because it is too costly to reinsure with core brokers for each core they might dismantle. As an answer to these challenging circumstances, core brokers in North America offer a Vehicle Identification Number (VIN)-based assessment of the individual vehicle's core value. By providing a VIN dismantlers receive a detailed list of vehicle components with the core broker's price offer, either through a web-based query at each core broker separately or through integrated solutions such as in yard management software (for example, CCC Pinnacle Yard Management, [www.cccis.com](http://www.cccis.com)) or stand-alone applications (for example, CorePricing, [www.car-parts.com](http://www.car-parts.com)). With integrated solutions, dismantlers can compare core prices of various core brokers instantly. Either type of system makes use of the mentioned databases to identify interchangeable components, though core brokers can still add their knowledge about interchangeability. The latter may cause differences in the interest of different core brokers in certain cores and their according price offers. To the author's information, the "additional interchange information" remains with the core broker. The e-procurement solution further facilitates the logistics processes as it provides, for example, shipping lists of dismantled parts. Dismantlers that use such systems mention its contribution to an improved decision making for dismantling, which derives from an easier value assessment, increased price transparency as well as the simplicity of sales, logistics and payment processes (groups I and J).

## DISCUSSION

Future sales strategies will most likely include the transfer of ownership, despite the promotion of leasing and renting models ('product service systems'). In such forward SCs, the collection and proper allocation of products and resources remains a challenging task. Therefore, it is important that independent reverse SCs can offer competitive services that address current challenges of these SCs. The e-procurement approach identified in North

American SCs for automotive cores offered by core brokers and used by dismantlers clearly demonstrates the SRM potential in independent SCs for remanufacturing.

Especially independent remanufacturers face competition of copies that substitute their remanufactured spare parts on the aftermarket while the demand for cores is increasing. The lead-time for core distribution and an overall increased supply can support remanufacturers. Core brokers play a crucial role as they link dismantlers and remanufacturers. The rivalry on the core broking market led to a consolidation of middleman (groups A, D, K). Resulting core broking companies reduce transaction and information costs due to several reasons. The e-procurement allows interacting with dismantlers who may have dealt with smaller core brokers before. Dismantlers (groups I, J) indicate that before the use of such tools core brokers tended to exploit them due to strong information asymmetries. The phenomena of exploitation by middleman in recycling SCs (Medina, 2015) seems to be similar in this case. The e-procurement with its ability to compare core prices increases the market transparency significantly. In addition, the e-procurement approach further increases the awareness of dismantlers for remanufacturing as an additional distribution channel. This channel was not always as clear as one might assume (groups I, J).

Dismantlers tend to favour quick payments (groups I, J). Dismantlers need incentives in order to considering core sales as an additional distribution channel. One of such incentives are short payment lead-times. A small core broker that visits each dismantling yard has the advantage of immediate quality checks and cash payments. Although the payment process can be longer with the distant core broking company, better core prices incentivise dismantlers. Due to objective quality standards communicated via the e-procurement tool and core brokers' websites (and irregular site visits by those brokers) combined with a software-aided shipment process, the core brokers can check shipped cores much faster and easier hence release payments accordingly (group J). Key informant 'I' identifies the e-procurement a game changer for many dismantlers.

The e-procurement solution has further advantages that can improve the supply with cores. Due to the increased transparency, dismantlers may decide to dismantle components that they did not dismantle before. A comparison of demand, quality requirements, prices and other transaction details with core brokers via e-mail, phone, or on-site requires enormous efforts hence increases information and transaction costs significantly. Furthermore, the vast and rapidly growing parts variety challenges small dismantlers. The e-procurement solution incorporates interchange information and the VIN-resolution makes it easy-to-use and fit-to-purpose for the dismantlers. The moment a vehicle is on the hoisting platform for depollution, one consultation of the VIN-based e-procurement platform issues a decision support in the form of core lists with prices and additional information (groups J, K).

E-procurement as identified in the core broking environment is a move towards more integrated organisations. Uncertainties about core quality and delivery lead-times combined with a dependence on cores as a key commodity for remanufacturing, as well as information asymmetries and further transaction costs explain this movement towards organisations between market and hierarchy in accordance with theory. Nevertheless, the initiative taken by core broking companies forecloses smaller core brokers. The latter might be one limitation of having a more efficient core broking process. However, dismantlers can increase their profits by circumventing middleman, which increases their motivation to consider selling to core brokers instead of scrap yards. Due to the increased transparency and reduced information asymmetries, core brokers constantly have to pursue competitive advantages. One such advantage is the core brokers' knowledge about interchangeable parts. Although the e-procurement does not reveal such information, a direct comparison of price offers also shows who may be interested in parts usually considered worthless and others may start to investigate such cases; this challenges the core brokers. In contrast, when innovative remanufactures identify new parts for remanufacturing, the corresponding demand information reaches the dismantlers through the upstream SC much faster than



through various middleman. Therefore, it may serve the triple bottom line from a systemic perspective as it facilitates increased reuse and remanufacturing quotas.

## CONCLUSION AND OUTLOOK

Independent market actors such as core brokers and independent remanufacturers have to face the challenge of increasing demand for cores while the SCs for remanufacturing becomes more data driven. First tier suppliers and OEMs that remanufacture already implement sophisticated SRM in their closed-loop SCs. The aspect of SRM is of great importance for core brokers and independent remanufacturers alike. The reduction of information and transaction costs, for example, through increased transparency, reduced lead-time and a reduced number of middleman, is crucial for the independent remanufacturing SC in order to oppose the much more integrated closed-loop SCs of OEMs. In case of core broking, SRM tools such as the discussed e-procurement tool used in the North American market can support the circular flow of used products into remanufacturing, but also into reuse in general. The example of a VIN-based tool for core identification and valuation does not only serve in automotive remanufacturing supply. Adopted to other industries, it could serve reuse and remanufacturing supply in general, e.g. for electronics such as TVs and displays or domestic appliances such as washing machines. Thereby, tools for the identification and management of end-of-life products and components can substantially support the objective of a circular economy.

Whether the e-procurement can significantly increase the amount of cores for remanufacturing purposes and thereby conserve resources needs to be further investigated, along with the evaluation of sustainability of parts remanufacturing which is most likely case-dependent. Furthermore, despite a wide range of represented market actors in the study group, the study provides only limited information directly collected from both European core brokers and dismantlers. During future research, the search for e-procurement solutions in automotive remanufacturing in Europe will continue. While core brokers may still be reluctant (as explained), selected key informants and dismantlers are already considered to complement the research data.

## ACKNOWLEDGEMENTS

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# ENVIRONMENT CONCIOUSNESS IN THE HUNGARIAN AUTOMOTIVE SUPPLY CHAINS – AN EMPIRICAL STUDY

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## **Abstract**

### **Purpose of this paper:**

The main purpose of this study is to find correspondence between the levels of traditional (non-green) supply chain management (SCM) and green supply chain management (GSCM) practices in Hungarian automotive industry. According our hypothesis, a high level of SCM practices has a positive effect on the adoption of GSCM methods.

### **Design/methodology/approach:**

The empirical data used in this study consists of questionnaire responses from Hungarian automotive supply chain enterprises. The questionnaire involved two sections: (1) aspects of SCM practices and (2) GSCM activities in the respondent organisation. The final sample contains 72 unique responses covering the whole supply chain from OEM to Tier4 suppliers.

### **Findings:**

We analysed the correspondence between SCM and GSCM practices with ANOVA, and created a correspondence matrix between GSCM fields and SCM methods. The results clearly verify our assumption that companies with more developed supply chain cooperation have more intensive GSCM activity. We also ranked SCM practices based on their effects on GSCM adoption, highlighting the most important synergies.

### **Value:**

Our study verifies, that supply chain cooperation brings additional value added also for GSCM. The results can be used for decision-making on developing SCM and/or GSCM practices.

### **Research limitations/implications:**

The limitation of the research is the relatively small sample, including only results from Hungary. Future researches may be done on automotive supply chains in other countries for international comparison and for a more complex view on the topic.

### **Practical implications:**

Results of this paper draw attention on the synergies between SCM and GSCM that can be considered in both SCM and GSCM development decisions.

## **1. INTRODUCTION**

It is becoming more and more proven that the impact of human activities on the environment is causing severe issues around the globe. Consequently, economic activities are increasingly beginning to consider environmental aspects. Researchers think that environmentally conscious/sustainable operation may give companies a competitive edge. Literature suggests that strategic goals cannot be achieved efficiently enough merely

through inter-organizational measures (e.g. by introducing an environmental management system). Operating our systems together with additional “shared values” along the entire value chain, taking advantage of chain synergies is much more efficient and effective.

The idea of environmentally conscious (green) supply chain management first began to take root in the literature in the early 1970s. The subject of our research, the fields of environmental management and supply chain management started to gain more and more ground in the 1980s. Integrating the two disciplines, the environmentally conscious (green) operation of supply chain management (the individual SCM fields: purchasing, logistics and production) came into focus in the 1990s. Economic organizations had to adapt and were even becoming more and more proactive, starting to look for potential synergies. Scientific research in the field (scientific theories, empirical research, modelling) started to be conducted around the turn of the century.

In the automotive industry this means that in the closely-knit systems based on OEM dominance, results get closer and closer to objectives as the given OEM starts to involve first-, second- and third tier suppliers into their environmental visions and processes.

## **2 LITERATURE REVIEW**

“Green Supply Chain Management” is the most accepted term in the literature for the idea of supply chain management that considers environmental aspects. Researchers in the field of Green Supply Chain Management (GSCM) approach the subject from two perspectives. One group of researchers (e.g. Shuvang et al. 2003, Srivastava 2008, Che 2010, Sarkis et al. 2011) define the aim of GSCM (as minimization of loss and waste, more environmental-friendly products or improvement of competitiveness). The other group of researchers (e.g. Hervani et al. 2005, Ninlawan et al. 2010, and Kalenoja et al. 2011) determine the activities and fields within GSCM, thus defining the idea of GSCM (green product design, green purchasing, green manufacturing, and green logistics). The term environmental or environmentally conscious supply chain management (ESCM or ECSCM), which can be found in the works of Zsidisin and Siferd (2001) or Beamon (2005), for example, is basically the equivalent of GSCM regarding its content. The concept of sustainable SCM (SSCM) is broader than GSCM, and takes also social aspects into consideration besides environmental ones (see e.g. Carter and Rogers 2008, Dakov and Novkov 2008, Rogers 2011, Harms 2011).

### ***2.2 Fields and methods of GSCM in light of technical literature***

The main direction of green supply chain management research is determining the fields of application and examining the applied management methods and techniques. The fields of GSCM relate to the individual stages of the supply chain and are the “green” equivalents of the field of inter-organizational supply chain management. Each area has its own set of tools facilitating environmentally conscious operation. In addition to these, there are general principles that cannot be clearly associated with any given area but can be classified as management methods by their nature. In accordance with the previous results found in literature, we applied four areas and one general management principle in our research:

#### **Green design, eco-design**

The aim of green design is the reduction of a product’s environmental impact during its whole life cycle without compromising other essential product criteria, such as performance and cost. Its most important tools are design for reduced consumption of hazardous materials, design for different kinds of reuse, and design for resource efficiency (see e.g. Dakov and Novkov 2008, Srivastava 2008, Zhu et al. 2008, Wooi and Zailani 2010, Eltayeb et al. 2011, Kim and Rhee 2012, Kumar et al. 2012, Lin 2013).

#### **Green purchasing**

The interpretation of green purchasing in the literature is quite uniform. The basic idea is decreasing the environmental impact caused by materials used in the products. (see e.g.

Ninlawan et al. 2010, Eltayeb et al. 2011, Chen et al. 2012, Chan et al. 2012). Cooperation with the suppliers is also emphasized. Methods and techniques include demanding supplier certifications, environmental management systems; supplier environmental auditing; establishing environmental requirements for purchased items; and professional and financial support to the supplier to reach environmental objectives.

### Green manufacturing

The purpose of green manufacturing is to improve the existing manufacturing procedures, in order to reduce emissions of harmful substances. Most scholars cite this as an independent GSCM field (e.g. Dakov and Novkov 2008, Srivastava 2008, Ninlawan et al. 2010, Chen et al. 2012, Kim and Rhee 2012, Kumar et al. 2012). Green manufacturing is most often aimed at reducing consumption of materials and energy, controlling harmful substances and integrating the various forms of recycling.

### Green logistics

The two main areas of green logistics are green distribution, which aims to reduce the environmental impact of packaging and transportation, and reverse logistics, which is necessary for the creation of a closed-loop supply chain. These activities are included in almost all sources dealing with this subject (see e.g. Dakov and Novkov 2008, Srivastava 2008, Ninlawan et al. 2010, Wooi and Zailani 2010, Eltayeb et al. 2011, Kim and Rhee 2012).

### Investment recovery

This management principle means the sale of excess inventories, materials, equipment, scrap materials with the aim of improving equipment usage. Besides the financial benefits, these methods also have a positive impact on the environment, which is cited for example in the works of Zhu et al. (2008) and Chen et al. (2012).

## 2.3 The characteristics and players of the Hungarian automotive supply chains

According to a survey conducted by PWC (2013) on the Hungarian automotive industry, the trends of Hungarian supplier networks follow the global trends, which means multi-layered (3-4 layers) networks dominated by international primary supplier companies. Hungarian companies tend to figure as second-, third- or even lower supplier levels.

Hungarian researchers of the field have unveiled significant discrepancies among the members in the automotive supply chain (Mészáros 2010, Antalóczy and Sass 2011, Havas 2010, PWC 2013), which is summarized in Figure 1. Among the discovered discrepancies, close cooperation, the management of the supplier network and innovative ability are important from the point of view of the subject at hand, as they are related to the development levels of SCM and GSCM.

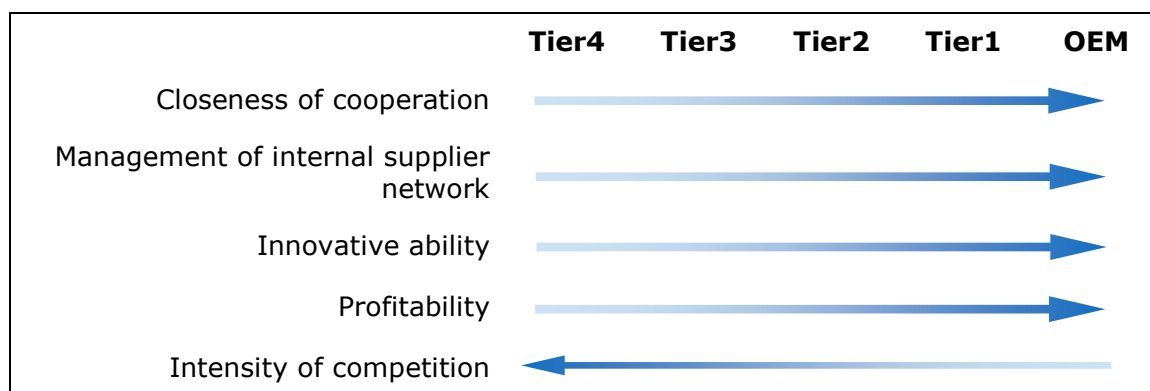


Figure 1: Discrepancies among the supplier levels in the automotive industry supply chain

Source: own figure based on Mészáros (2010), Antalóczy and Sass (2011), Havas (2010), PWC (2013)

### 3. MATERIALS AND METHODS

#### 3.1 Research hypothesis and method

The most important question of the research was whether the development of the traditional supply chain management at the studied companies was in correlation with the development of green supply chain management. According to our hypothesis, **the more developed a company's traditional supply chain management system is, the more developed its green supply chain management will be**. We stipulated, therefore, that the closer the cooperation is among the partners within the given supply chain, the more likely the members of the chain are to use GSCM methods as well.

The hypothesis was tested using a questionnaire-based survey. A part of the questions concerned the traditional supply chain management activities of companies, while the rest of the questions involved the application of the various fields and methods of green supply chain management.

From the toolkit of traditional supply chain management, we studied the effects of cooperation among the members of the supply chain and supplier-customer relationships. The top **SCM fields** studied are:

- information sharing among the members of the supply chain (5 subquestions)
- forms of cooperation – mutual decision-making, planning, work groups (5 subquestions)
- investment into the partnership (3 subquestions)
- commitment to partnership (5 subquestions).

Respondents were asked to check one of the three options below:

*I don't use the SCM method at all*

*I only use the SCM method with key partners*

*I use the SCM method with multiple partners*

In studying **GSCM activity**, we surveyed the areas listed in section 2.2. The areas included in the questionnaire are the following:

- Green design (3 methods)
- Green purchasing (10 methods)
- Green manufacturing (4 methods)
- Green logistics (5 methods)
- Investment recovery (3 methods)

Here are the answer choices and their related scores:

*I don't use it and I don't plan to* 0

*I don't use it but I plan to* 1

*Under launch/implementation* 2

*I have used it for less than 1 year* 3

*I have used it for more than 1 year* 4

We used an intensity index to evaluate the development level of GSCM areas. The index was calculated as the arithmetic average of the scores based on the responses that belong to the given area. The intensity index is thus measured on a scale between 0 and 4. The higher the index, the more developed the given GSCM area at the respondent company.

We grouped the companies into categories based on the answers given to each of the SCM questions, then used ANOVA to compare the GSCM-intensity of groups created based on SCM activity. The analysis was prepared using LSD and Games-Howell post-hoc tests.

#### 3.2 Companies participating in the research

The subjects of the primary research were automotive manufacturers operating in Hungary and their suppliers. The research questionnaire was sent to 350 companies belonging to the target group between July 2014 and November 2015. We got 75 questionnaires back,

out of which 72 were properly filled and appropriate for statistical processing. This accounts for a 21% response rate.

66.7% of the respondent companies are Hungarian, while 33.3% are of foreign majority ownership. Regarding number of employees, the sample companies include small, medium and large enterprises: 22 companies (30.6%) employ 50 persons or fewer, 25 companies (34.7%) have a staff of between 51 and 250 employees, and 25 companies (34.7%) are large enterprises with over 250 employees.

#### **4. RESULTS AND DISCUSSION**

According to the ANOVA results, 45 out of the 90 SCM method – GSCM area pairs, i.e. in 50% of the cases, there is significant difference in GSCM intensity among groups created based on SCM methods. Table 1 shows the pairs where this difference was significant at a 95% confidence level.

SCM method group	SCM method	Green design	Green purchasing	Green manufacturing	Green logistics	Investment recovery	Frequency of incidence
Information sharing	Partners inform each other of changing needs		✓	✓	✓	✓	4
	Partners hold regular personal consultation	✓	✓	✓	✓		4
	Partners give each other feedback on performance		✓		✓		2
	Partners share all information that may help the other						0
	Partners share information even when it is sensitive from a business point of view						0
Cooperation	There is consensus in the management that the supplier needs to be involved in the design process	✓	✓	✓	✓	✓	5
	Cooperation in planning and solving operative issues	✓	✓	✓	✓		4
	The supplier take part in product design	✓	✓	✓	✓		4
	Establishing joint workgroup(s) with partner company	✓	✓	✓	✓		4
	Partners consolidate their decisions in the interest of cost efficiency	✓	✓		✓		3
Investment into partnership	The company has made significant financial investment in order to improve cooperation	✓	✓	✓	✓		4
	The company has made HR-investment in order to improve cooperation	✓	✓	✓			3
	The company has shared their protected know-how or technology with their partner in order to facilitate cooperation	✓	✓				2
Commitment to partnership	The company is planning to maintain the cooperation for the long-term	✓	✓				2
	The company's partner is planning to maintain the cooperation for the long-term	✓	✓				2
	Purchasing decisions are typically not based on price		✓		✓		2
	The company shares the jointly realized profits with the supplier						0
	The company typically makes hedge contracts with suppliers to protect its own interests						0
Frequency of incidence		11	14	8	10	2	45

Table 1: Correlation between traditional and green supply chain management  
Source: own research

According to the table, the most differences between the intensity of GSCM methods between groups based on SCM are measured the area of **green purchasing**: it affects 14 out of 18 SCM methods. The post hoc tests show that the more intensive use of SCM methods correspond to a higher intensity rate for green purchasing, which means that generally well-developed supplier-customer relationships can be effectively utilized in green purchasing.

The area of **green design** also shows significant differences between the groups for several (11) SCM methods, which typically affects the areas of cooperation and investment in partnerships. More developed SCM was associated with a higher level of development in green product design. Close supplier-customer relationships may facilitate joint development and cooperation in designing products with environmental-friendly features as well as in negotiations regarding needs.

Another area that showed significant differences for several (10) SCM methods was **green logistics**, where post hoc tests matched the results of the two areas presented above.



Cooperation can support the logistics activities such as transportation, packaging and inverse logistics, especially through information-sharing and cooperation.

Fewer (8) SMC methods showed significant differences between the groups for **green manufacturing**. This result is surprising, given the fact that manufacturing is an internal process, meaning that suppliers have a lesser impact on it than on other elements of the supply chain that are closer to them, such as purchasing or logistics. Certain cases of information sharing and cooperation may have a positive impact on the application of green methods, however.

The study of **investment recovery** did not give relevant results, which corresponds to our expectations given the lack of logical connection.

The **importance of cooperation** is exceptional among **traditional SCM areas**. All methods discussed in the questionnaire showed significant differences in all GSCM areas. It can be concluded that companies using forms of cooperation more intensively in their partnerships have a higher development rate in GSCM areas.

Two methods stood out in the area of **information-sharing**: prompt notification of changed needs and regular personal consultations. Based on these results, successful GSCM is not conditioned upon partners sharing confidential or wide-ranging information.

Companies that are willing to **invest in partnerships** achieved better results in the areas of green design, green purchasing and partly in green manufacturing.

We used post-hoc tests to uncover significant correlations between groups created based on SCM methods. The results point to three typical patterns, which are illustrated in Figure 2.

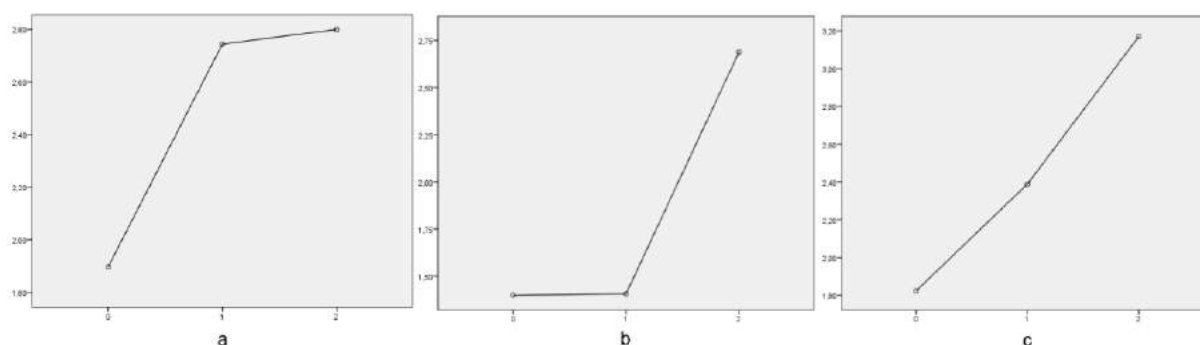


Figure 2: typical examples of the GSCM development of groups created based on SCM methods

(the horizontal axis shows the categories established based on SCM methods, while the vertical axis shows the GSCM intensity index)

Source: own research

In most of the cases (21 incidences), the GSCM development level of groups not applying the SCM method was significantly lower than the two groups using the SCM method. However, the results did not show significant differences between groups using the SCM method with just a few or multiple partners. This pattern was also typical for most of the methods within the category of Cooperation, regardless of the GSCM area studied. This is illustrated by Figure 2/a.

No significant difference in GSCM development was observed in 9 cases between the groups that did not apply the SCM method or only with a few partners, while those who applied the method with multiple partners performed considerably better. This pattern was typical of various forms of information sharing, regardless of the GSCM area studied. This is illustrated by Figure 2/b.

The GSCM development of groups applying traditional SCM methods more and more intensively showed gradually higher levels in 3 cases (see Figure 2/c). This pattern was observed with Joint work groups.

The results clearly confirm our hypothesis that companies with a higher development level of traditional supply chain management activity also have a more well-developed green supply chain management system. The results thus verify the hypothesis.

## 5 SUMMARY

Our main research question concerned the impact of traditional supply chain management on the application of green supply chain management in the Hungarian automotive supply chains. When studying this issue, it was essential to clear the picture of the areas and principles of green supply chain management (these two are sometimes confused in the international GSCM literature). Within each area and principle, we identified the toolkit that facilitates environmentally conscious operation. We analysed the connection between traditional SCM and GSCM with ANOVA and post-hoc tests. The analyses gave positive results regarding the impact of cooperation, some methods of information sharing and investments dedicated to partnerships. Green purchasing, green design and green logistics proved to have the closest relationship with the use of SCM methods.

As an overall summary, it can be stated, that supply chain cooperation brings additional value also to GSCM. Moreover, this process is expected to continue: nowadays there is a lot of discussion on the future of artificial intelligence — smart factory (or Industry 4.0). Only future will tell how smart supply chains will effect sustainability and environmental issues.

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# **A REVENUE-BASED SLOT ALLOCATION AND PRICING FRAMEWORK FOR MULTIMODAL TRANSPORT NETWORKS**

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## **ABSTRACT**

This paper analyses the operational integration between different multimodal transport services and proposes a slot allocation and pricing model for multimodal transport networks to maximize revenue and utilize capacity. The methodology entails a revenue-based optimal two-stage approach. Firstly, a slot allocation model is formulated by using stochastic integer programming for long-term contract market sale where the predetermined or negotiated price tariffs are used for regular orders. Secondly, a stochastic nonlinear programming is formulated to solve the slot allocation and dynamic pricing on short-term spot market sale for temporal as well as last-minute orders. Finally, a case study is provided to demonstrate an efficient and effective use of the proposed model.

## **INTRODUCTION**

The changing structure of the transport business driven by high cost efficiency, increased competition, demand pressure, less pollution, strict traffic and customs regulations has led shippers to immediately use multimodal freight transport services (Kayikci, 2014). The one hand, shippers seek the cost efficient, quality effective and faster services, on the other hand multimodal transport service providers (MTPs) offer the services timely and faster with appropriate slot allocation and pricing strategy in order to maximize revenue. Multimodal transport describes a multi-unit transport chain in which transport are conveyed with at least two different transport modes (i.e. rail-road, river-road, sea-road, sea-rail) on the basis of a multimodal transport contract from a place (origin) in one country at which transport units are taken in charge by the multimodal transport providers in transport means (e.g. RoRo vessel, RoLa train) to a designated place (destination) for delivery in a different country (UN, 1980). A typical transport chain consists of three separated segments: pre-haulage, main-haulage and end-haulage. The sections for pre- and end-haulage refer short-distance and transport units (e.g. RoRo-units, containers, trailers) are mostly transported by road between customers and terminals/ports and vice versa, while main-haulage refers long-distance and transport units are shipped by vessels from one port to another and/or transported by rail from one terminal to another. Main-haulage consists of the combination of several sea-rail connections or modal shifts (transshipments), where MTPs establish often a consortium (e.g. liner shipping provider, railway freight provider) and this is responsible for the performance of entire haulage contract from origin to destination (OD) and also capacity management of transport means. Also, an MTP, which is mainly liner shipping provider, can rent block train services as a company train rather than using public train services of other railway freight providers and it offers a seamless trip between OD to the shippers by taking the whole trip responsibility. Block train enables MTPs that all storage units are shipped from the same point and arrive at the same destination, so that trip can be realized without having any transshipment within OD, uninterrupted and faster. This research focuses on the main-haulage part of transport network.

The development of the multimodal transport system relies on the construction of networked comprehensive cargo hub (multimodal hub) system. These cargo hubs provide transport mode transfer for the multimodal transport services. They usually have stockyard for stacking transport units, as well as dispatching and configuration of freight trains,

vessels or vehicles. Meanwhile, they have good highway connections, railway facilities, seaport and well-tuned information systems, which are essential for the freight transport services and helpful for tracking, managing and controlling the freight flow (Lowe, 2005). Beside this, the capacity management including route planning and vessel/train scheduling is likely to be a crucial success factor for the sustainability of multimodal transport (Kayikci, 2014). Inadequate capacity utilization may cause dramatic losses for MTPs. Therefore, a high level of collaboration and seamless integration is significant. The capacity of freight trains and vessels is generally being utilized at a rate of over 70% per trip (Kayikci, 2014). In this respect, revenue management (RM) strategies and technologies may help MTPs to improve load factor (capacity utilization rate) and margins of their services.

The context of multimodal freight transport has been extensively studied in literature (SteadieSeifi, et al. 2014). A large number of research efforts have been focused on transport planning problems at the strategic, tactical and operational decision-making levels. However, a successful implementation of multimodal freight transport and also other innovative transport solutions not only depend on efficient transport planning and control, but also on an appropriate slot allocation and pricing strategy for multimodal freight services (Li et al., 2010; Cho et al., 2012; Tao, 2013). In the multimodal transport industry, like in airline industry, in practice there are two different as well as related components of multimodal transport revenue maximization (Belobaba et al., 2009): *differential pricing*: various shipper products ("fare products") are offered at different price categories (dynamic or fixed price options) with different characteristics for freight transport in the same OD route; *revenue management*: This process determines the number of slots (space occupied by a transport unit in a vessel or a train) to be made available to each shipper class ("fare class" for booking a slot) on a transport means, by setting booking limits (capacity control) on fare slots. The pricing strategy has a great impact on the profitability as well competitiveness of multimodal freight services and also it plays an important role for the shippers to decide on transport mode. A pricing strategy based on a single price for all available slots is an imperfect compromise to maximize revenue, therefore the price segmentation should be applied. A pricing strategy depends mainly on transport cost, price sensitivity, and competition (Reis et al., 2013; Li et al., 2010), but also there are many factors for pricing multimodal freight transport involved in determining how much shippers should be charged by using each service with specific service-related characteristics such as origin node (loading), destination node (discharging), type of transport means, the number and type of transport units, transport time, delivery time and also time of reservation. Usually one or more of these factors vary significantly across market segments. The purpose of this research is to present a dynamic slot allocation and pricing framework for MTPs which operate together.

The rest of the paper is organized as follows: First, a revenue-based slot allocation and pricing model is described, then the solution model is developed, afterwards a case study is applied into the model, finally the paper is completed with findings and conclusion.

## **A REVENUE-BASED SLOT ALLOCATION AND PRICING MODEL**

A revenue-based slot allocation and pricing model is depicted in Figure 1. This model solely considers sea and rail transport in a multimodal transport network, whereas road transport is kept out of the model. Although in the practice the pricing strategies for each transport mode are mainly determined as fixed pricing according to km-distance to be travelled between OD, in this model, we used shipper classes in order to determine pricing strategies. Three shipper classes are identified, namely (Kayikci, 2014): (1) *contractual shipper* regularly ships large quantities of transport units and is characterized with a fixed-commitment contract and negotiated market price; a certain slot allotment (protect slots) is reserved on transport means over a period of time where the orders of major shippers and forwarders have priority to get fulfilled (Lee, et al, 2007). (2) *ad-hoc shipper* buys slot with spot market price; this type of shippers is temporal and this fare is offered only for a certain sales time period (i.e. until one-two weeks before the departure date of vessel or

train). (3) *urgent shipper* typically seeks a free slot in the last minute and is willing to pay a high fare for the last-minute freight services. The highest spot market rate in the sales time period is preferably allocated to the urgent shippers. The contractual shippers make an agreement with consortia on the number of shipped transport units per year, therefore there are protected slots at each vessel and rail to reserve for contract market sale. Since the ad-hoc and urgent orders generates higher revenue, it is optimal to accept as many orders for spot market sale as possible (Lee, et al. 2007). Because of this predictable behaviour, the freight demand of contractual shipper is certain, whereas the demand is uncertain for urgent and ad-hoc shippers. The price strategy depends on the relationship between the supply capacity (the number of available slots) and demand forecast (number of shipper orders). If the demand is greater than the supply, there is a shortage. If the supply increases, the price decreases, and if the supply decreases, the price increases.

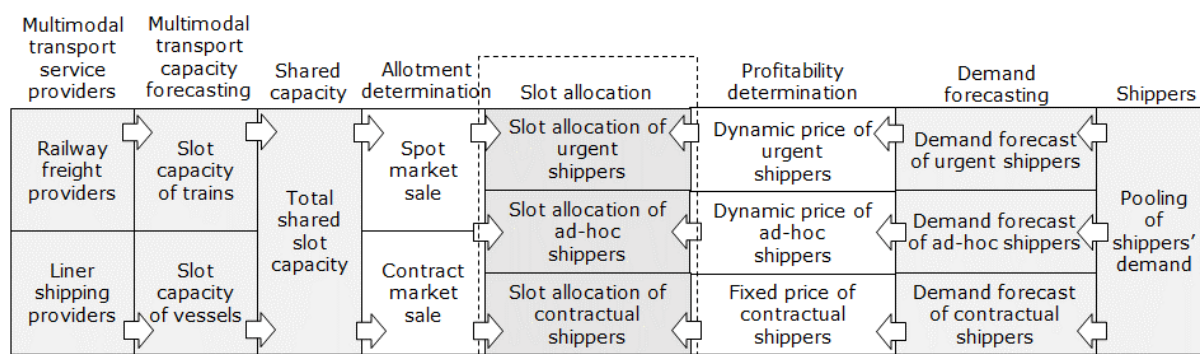


Figure 1: A revenue-based slot allocation and pricing model in multimodal transport

The total shared slot capacity indicates the total available slots on transport units, e.g. on both train and vessel. Operationally, capacity of transport units depends on the density of booked shipments and their shapes as well as the dead weight restriction. Also, the transport unit mix in relation to movable decks, internal ramps, lane heights etc., can be a limiting factor as to how much cargo in a vessel or train wagon can accommodated. In the model, it is also necessary to determine how much slot capacity should be allocated to the contractual shippers for contract market sale. For that the MTPs make decision on the limitation of allotments, as this would affect also the profitability. The seasonality of cargo movements (peak and low season), directional cargo imbalances (import vs. export), minimum scale (the number and size of vessels and/or trains) and so on play important role to decide on the percentage of allotments.

## METHODOLOGY

The methodology entails a revenue based optimal two-stage approach. Firstly, a slot allocation model is formulated by using stochastic integer programming for long-term contract market where the pre-determined price tariffs are used for regular customer class. Secondly, a stochastic nonlinear programming is formulated to solve the slot allocation and dynamic pricing for spot market.

### Assumptions:

Supply capacity for shared slots and demand forecasts are equal.

All transshipments are loaded freights.

Only semi-trailers are shipped as transport unit.

All trips which made either vessels or rails are round trips, different prices can be assigned for every OD direction due to importing/exporting freight. The freight rate is calculated according to combined sea-rail legs, there is no separate calculation.

There is no additional cargo demand (semi-trailer) available for loading from the cargo-hub ( $H$ ) to vessel and train.

The average freight rate of each OD node pair for contractual shippers is determined in advanced on negotiation.

There are no cancellations and no-shows.

*Indices and parameters:*

$i$  = the index of loading node (origin node) of the freight flow,  $i = 1, 2, \dots, m$

$j$  = the index of discharging node (destination node) of the freight flow,  $j = 1, 2, \dots, n$

$V$  = the index of nodes for seaport terminal,  $V = \{v_i | i = 1, \dots, n\}$

$R$  = the index of nodes for railway inland terminal,  $R = \{r_j | j = 1, \dots, n\}$

$E$  = the edge from/to OD pair,  $E = \{(v_i, r_j) / (r_i, v_j) | v_i \in V, r_j \in R\}$

$k$  = the index of trip for vessel or train,  $k = 1, 2, \dots, l$ . Each trip is constrained by the maximum serviceable capacity

$Q$  = the total slot capacity of multimodal line,  $Q = Q^v + Q^r$

$Q^v$  = the slot capacity of vessel

$Q^r$  = the slot capacity of train

$Q_k^v$  and  $Q_k^r$  = the available slot capacity of  $k^{th}$  trip for vessel or train

$MA$  = the maximum slot allotment of contractual shippers (protect slots)

$p_{ij}^c$  and  $p_{ji}^c$  = slot price for contractual shippers at the  $t^{th}$  booking period of contract market sale from/to OD pair respectively for outward ( $v_i, r_j$ ) and return trip ( $r_i, v_j$ )

$P_{ijt}^{su}$  and  $P_{jit}^{su}$  = upper price limit at the  $t^{th}$  booking period of spot market sales from/to OD pair respectively for outward ( $v_i, r_j$ ) and return trip ( $r_i, v_j$ )

$P_{ijt}^{sl}$  and  $P_{jit}^{sl}$  = lower price limit at the  $t^{th}$  booking period of spot market sales from/to OD pair respectively for outward ( $v_i, r_j$ ) and return trip ( $r_i, v_j$ )

$p_{ijt}^s$  and  $p_{jit}^s$  = slot price at the  $t^{th}$  booking period of spot market sales from/to OD pair respectively for outward ( $v_i, r_j$ ) and return trip ( $r_i, v_j$ ), where the slot price for  $t = 1, 2, \dots, T - 1$  is allocated for ad-hoc shippers, whereas  $t = T$  for urgent shippers

$T$  = booking period for spot market sales,  $t = 1, 2, \dots, T - 1, T$ , which can be divided into the sub-periods e.g. days, weeks.

*Decision variables:*

$x_{ij}^c$  and  $x_{ji}^c$  = slot demand for contractual shippers at the  $t^{th}$  booking period of contract market sale from/to OD pair respectively for outward ( $v_i, r_j$ ) and return trip ( $r_i, v_j$ ).

$x_{ijt}^s$  and  $x_{jit}^s$  = slot demand at the  $t^{th}$  booking period of spot market sale from/to OD pair respectively for outward ( $v_i, r_j$ ) and return trip ( $r_i, v_j$ ), where the slot demand for  $t = 1, 2, \dots, T - 1$  is allocated for ad-hoc shippers, whereas  $t = T$  for urgent shippers.

We assumed that the demand function is linear  $x_{ijt}^s = a_{ijt} - b_{ijt} \cdot p_{ijt}^s$ ,  $a_{ijt}, b_{ijt} > 0, \forall t$  and  $x_{jit}^s = a_{jit} - b_{jit} \cdot p_{jit}^s$ ,  $a_{jit}, b_{jit} > 0, \forall t$ , where the demand function coefficients,  $a$  and  $b$  are estimated for each  $t^{th}$  booking period using statistical methods (e.g. regression analysis) for round-trip (Thiele, 2006). The demand in spot market is uncertain and fluctuated randomly, therefore dynamic price need to be included. Actual value of demand function coefficients  $a_{ijt}$  and  $b_{ijt}$  is denoted with  $\tilde{a}_{ijt}$  and  $\tilde{b}_{ijt}$  for OD pair as to outward ( $v_i, r_j$ ) and return trip ( $r_i, v_j$ ),  $\tilde{a}_{ijt} \in [a_{ijt} - \hat{a}_{ijt}, a_{ijt} + \hat{a}_{ijt}]$ ,  $\tilde{b}_{ijt} \in [b_{ijt} - \hat{b}_{ijt}, b_{ijt} + \hat{b}_{ijt}]$  sowie  $\tilde{a}_{jit} \in [a_{jit} - \hat{a}_{jit}, a_{jit} + \hat{a}_{jit}]$ ,  $\tilde{b}_{jit} \in [b_{jit} - \hat{b}_{jit}, b_{jit} + \hat{b}_{jit}]$ , where  $\hat{a}$  and  $\hat{b}$  indicate the variation in coefficients. Deviation degrees for  $\alpha_{ijt}, \beta_{ijt} \in [-1, 1]$  between the actual value  $\tilde{a}_{ijt} | \tilde{b}_{ijt}$  and the estimated value  $a_{ijt} | b_{ijt}$  are included, which makes  $\tilde{a}_{ijt} = a_{ijt} + \hat{a}_{ijt} \alpha_{ijt}$ ,  $\tilde{b}_{ijt} = b_{ijt} + \hat{b}_{ijt} \beta_{ijt}$ . The absolute value of the differences between actual and nominal demand at the  $t^{th}$  booking period is  $\tau_{ijt}^s = \hat{a}_{ijt} \alpha_{ijt} - \hat{b}_{ijt} \beta_{ijt} \cdot p_{ijt}^s$  for outward trip ( $v_i, r_j$ ), similar  $\tau_{jit}^s = \hat{a}_{jit} \alpha_{jit} - \hat{b}_{jit} \beta_{jit} \cdot p_{jit}^s$  for return trip ( $r_i, v_j$ ). The lesser the  $\tau$  value, the higher the demand function involvement from MTPs. This  $\min \tau$  is added in the objective function for spot market sale.

$V_{ijk}^c$  = trip length;  $V_{ijk}^c = 1$ , if vessel trip  $k$  is the part of OD pair for outward trip ( $v_i, r_j$ ) in contractual market sale, otherwise  $V_{ijk}^c = 0, \forall k$ .

$V_{jik}^c$  = trip length;  $V_{jik}^c = 1$ , if vessel trip  $k$  is the part of OD pair for return trip ( $r_j, v_i$ ) in contractual market sale, otherwise  $V_{jik}^c = 0, \forall k$ .

$R_{ijk}^c$  = trip length;  $R_{ijk}^c = 1$ , if rail trip  $k$  is the part of OD pair for outward trip ( $v_i, r_j$ ) in contractual market sale, otherwise  $R_{ijk}^c = 0, \forall k$ .

$R_{ijk}^c$  = trip length;  $R_{ijk}^c = 1$ , if rail trip  $k$  is the part of OD pair for return trip  $(r_j, v_i)$  in contractual market sale, otherwise  $R_{ijk}^c = 0, \forall k$ .

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$V_{jik}^s$  = trip length;  $V_{jik}^s = 1$ , if vessel trip  $k$  is the part of OD pair for return trip  $(r_j, v_i)$  in spot market sale, otherwise  $V_{jik}^s = 0, \forall k$ .

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$R_{jik}^s$  = trip length;  $R_{jik}^s = 1$ , if rail trip  $k$  is the part of OD pair for return trip  $(r_j, v_i)$  in spot market sale, otherwise  $R_{jik}^s = 0, \forall k$ .

### Objective functions

The objective function of the model is to maximize the total freight contribution for contract and spot market sale.

$$\text{Max } Z = \text{Max } Z(\text{contract}) + \text{Max } Z(\text{spot}) \quad (1)$$

**Contract market sale:** The objective function of the model for contract market sale is to maximize the total freight contribution from the shipment of contractual shippers for round trip. This is represented in equation (2).

$$\text{Max } Z(\text{contract}) = \sum_{i=1}^m \sum_{j=1}^n p_{ij}^c \cdot x_{ij}^c + \sum_{j=1}^n \sum_{i=1}^m p_{ji}^c \cdot x_{ji}^c \quad (2)$$

**Spot market sale:** The objective function of the model for spot market sale is to total freight contribution from the shipment of ad-hoc shippers as well as urgent shippers. This is represented in equation (3).

$$\text{Max } Z(\text{spot}) = \sum_{i=1}^m \sum_{j=1}^n \sum_{t=1}^{T-1} p_{ijt}^s \cdot x_{ijt}^s + \sum_{j=1}^n \sum_{i=1}^m \sum_{t=1}^{T-1} p_{jit}^s \cdot x_{jit}^s + \sum_{i=1}^m \sum_{j=1}^n \sum_{t=T-1}^T p_{ijt}^s \cdot x_{ijt}^s + \sum_{j=1}^n \sum_{i=1}^m \sum_{t=T-1}^T p_{jit}^s \cdot x_{jit}^s \quad (3)$$

$$\text{Max } Z(\text{spot}) = \left( \sum_{i=1}^m \sum_{j=1}^n \sum_{t=1}^{T-1} p_{ijt}^s (a_{ijt} - b_{ijt} \cdot p_{ijt}^s) + \min \sum_{i=1}^m \sum_{j=1}^n \sum_{t=1}^{T-1} p_{ijt}^s (\hat{a}_{ijt} \alpha_{ijt} - \hat{b}_{ijt} \beta_{ijt} \cdot p_{ijt}^s) \right) + \dots$$

### Constraints:

#### (a) Vessel constraints:

$$\sum_{i=1}^m \sum_{j=1}^n \sum_{k=1}^l x_{ij}^c V_{ijk}^c + \sum_{i=1}^m \sum_{j=1}^n \sum_{t=1}^T \sum_{k=1}^l x_{ijt}^s V_{ijk}^c \leq \sum_{k=1}^l Q_k^v = Q^v, \forall k \quad (4)$$

$$\sum_{j=1}^n \sum_{i=1}^m \sum_{k=1}^l x_{ji}^c V_{jik}^c + \sum_{j=1}^n \sum_{i=1}^m \sum_{t=1}^T \sum_{k=1}^l x_{jit}^s V_{jik}^c \leq \sum_{k=1}^l Q_k^v = Q^v, \forall k \quad (5)$$

$$\sum_{i=1}^m \sum_{j=1}^n \sum_{k=1}^l x_{ij}^c V_{ijk}^c \text{ and } \sum_{j=1}^n \sum_{i=1}^m \sum_{k=1}^l x_{ji}^c V_{jik}^c \leq MA \quad (6)$$

#### (b) Train constraints:

$$\sum_{i=1}^m \sum_{j=1}^n \sum_{k=1}^l x_{ij}^c R_{ijk}^c + \sum_{i=1}^m \sum_{j=1}^n \sum_{t=1}^T \sum_{k=1}^l x_{ijt}^s R_{ijk}^c \leq \sum_{k=1}^l Q_k^r = Q^r, \forall k \quad (7)$$

$$\sum_{j=1}^n \sum_{i=1}^m \sum_{k=1}^l x_{ji}^c R_{jik}^c + \sum_{j=1}^n \sum_{i=1}^m \sum_{t=1}^T \sum_{k=1}^l x_{jit}^s R_{jik}^c \leq \sum_{k=1}^l Q_k^r = Q^r, \forall k \quad (8)$$

$$\sum_{i=1}^m \sum_{j=1}^n \sum_{k=1}^l x_{ij}^c R_{ijk}^c \text{ and } \sum_{j=1}^n \sum_{i=1}^m \sum_{k=1}^l x_{ji}^c R_{jik}^c \leq MA \quad (9)$$



(c) Total slot capacity constraint for multimodal freight transport:

The total allocated slot number for contract and slot market sale cannot exceed the total slot capacity of multimodal freight transport, as shown in equation (10), total slot capacity is the sum of the available shared capacity of the total vessel operational capacity and train operational capacity, seen in equation (11).

$$\sum_{i=1}^m \sum_{j=1}^n x_{ij}^c + \sum_{i=1}^m \sum_{j=1}^n \sum_{t=1}^T x_{ijt}^s \leq Q \quad (10)$$

$$Q = \sum_{k=1}^l Q_k^v + \sum_{k=1}^l Q_k^r \quad (11)$$

(d) Freight demand constraint:

The allocated slots to each OD leg must be set between the interval of the lower and upper bound of freight price at the  $t^{th}$  booking period of spot market sales for outward  $(v_i, r_j)$  and return trip  $(r_i, v_j)$  respectively, seen in equation (12) and (13). The price for spot market sale cannot be lower than the price for contract market sale. This also helps to keep the capacity utilization at certain rate.

$$P_{ijt}^{sl} \leq x_{ijt}^s \leq P_{ijt}^{su} \quad \forall i, j \text{ and } t \quad (12)$$

$$P_{jit}^{sl} \leq x_{jit}^s \leq P_{jit}^{su} \quad \forall i, j \text{ and } t \quad (13)$$

## CASE STUDY

An Istanbul based consortium of MTPs provides a number of sea and rail transport services to shippers and has a fixed transport capacity on each link of the multimodal network. Shippers search slots for semi-trailers to reserve available space on vessel and rail. MTPs allocate shared slots capacity for the three classes of shippers with three legs from Istanbul ( $v_1$ ) to Salzburg ( $r_1$ ) and Ludwigshafen ( $r_2$ ) through sea-rail transshipment. Transshipment takes place in Trieste ( $H$ ).

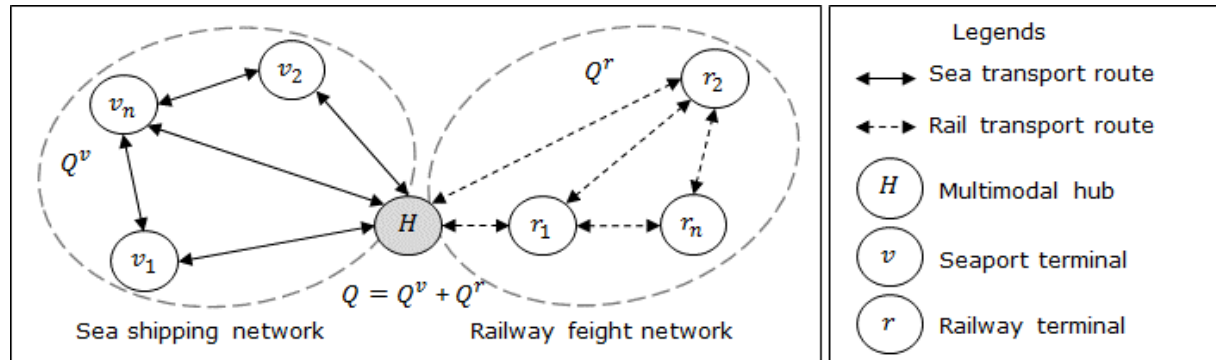


Figure 2: The multimodal freight transport network

The multimodal transport network is arranged in several railway legs and sea shipping voyages as shown in Figure 2. This network can be defined through a graph, i.e.  $M = (H, V, R, E)$  that models the network structure, where  $V$  is a set of nodes for seaport terminal,  $V = \{v_i | i = 1, \dots, n\}$ ,  $R$  is a set of nodes for railway inland terminal (hinterland),  $R = \{r_j | j = 1, \dots, n\}$  and  $H$  denotes the cargo hub for multimodal transport where both loading and discharging operations of vessels and trains are carried out. In a multimodal transport network, many cargo hubs can be operated for modal shift. A combination of one railway node and one sea shipping node refers an OD pair of multimodal freight flow which is shown with edge  $E = \{(v_i, r_j) | v_i \in V, r_j \in R\}$ . Railway freight provider operates rail services (i.e. RoLa, ISU) to/from the ports/terminals, which are specially designed wagons to carry wheeled cargo by rail. Liner shipping provider has a fleet of vessels (i.e. RoRo), which are specially types of ships designed to carry wheeled cargo. Their transport units can be trucks, semi-trailer trucks, trailers, automobiles, railroad cars, project cargo, and maritime containers on MAFIs or cassettes. The railway freight provider operates round-trip daily

RoLa train service with six/leg from cargo hub to two railway inland terminals ( $H - r - H$ ). The train capacity ( $Q_k^r$ ) is 32 semi-trailers/trip. The liner shipping provider operates round-trip daily RoRo vessel service with one/line from seaport to cargo hub ( $v - H - v$ ). The vessel capacity ( $Q_k^v$ ) is 240 semi-trailers/trip. The maximum shared capacity from one port to other terminal for each trip is 192 and each trip is completed via sea and rail transport. There is one sea trip and four rail trips between ( $v_1 - r_1$ ), whereas there is one sea trip and two rail trip between ( $v_1 - r_2$ ) for both outward and return legs.

Booking periods of spot market sale	OD	$t = 1$	$t = 2$	$t = 3$
Estimation of demand function coefficients $a_{ijt}$ and $b_{ijt}$ for outward trip	$v_1 - r_1$	150, 0.053	85, 0.022	33, 0.013
	$v_1 - r_2$	90, 0.047	45, 0.015	20, 0.008
Variation of demand function coefficients $\hat{a}_{ijt}$ and $\hat{b}_{ijt}$ for outward trip	$v_1 - r_1$	15, 0.005	15, 0.005	15, 0.005
	$v_1 - r_2$	10, 0.005	10, 0.005	10, 0.005
Estimation of demand function coefficients $a_{jit}$ and $b_{jit}$ for return trip	$r_1 - v_1$	130, 0.048	102, 0.019	21, 0.008
	$r_2 - v_1$	53, 0.041	28, 0.016	13, 0.006
Variation of demand function coefficients $\hat{a}_{jit}$ and $\hat{b}_{jit}$ for return trip	$r_1 - v_1$	15, 0.005	15, 0.005	15, 0.005
	$r_2 - v_1$	10, 0.005	10, 0.005	10, 0.005

Table 1: Estimation and variation of demand function coefficients in booking periods

Node Pair ( $v_i, r_j$ )( $r_i, v_j$ )	contractual shipper (no $t$ limitation)		ad-hoc shipper ( $t = 1, \dots, T - 1$ )				urgent shipper ( $t = T$ )	
time period	$t = 0$		$t = 1$		$t = 2$		$t = 3$	
OD	Price	Demand	Price	Demand	Price	Demand	Price	Demand
$v_1 - r_1$	1628	40	1863	68	1900	13	2023	7
$v_1 - r_2$	1488	13	1813	42	1928	7	1968	2
$r_1 - v_1$	1628	35	1948	71	2030	18	2115	4
$r_2 - v_1$	1488	18	1898	34	1998	8	2061	4
Revenue	€ 168.228		€ 405.670		€ 90.720		€ 34.801	
Total	€ 699.419							

The transport unit price of semi-trailer is in Euro. Maximum allotment for contract market sale is 30%. Trip capacity is 100%.

Table 2: Differentiated scenario: slot allocation and pricing strategy according to dynamic pricing conditions in booking period  $t$

Node Pair ( $v_i, r_j$ )( $r_i, v_j$ )	contractual shipper (no $t$ limitation)		ad-hoc shipper ( $t = 1, \dots, T - 1$ )				urgent shipper ( $t = T$ )	
time period	$t = 0$		$t = 1$		$t = 2$		$t = 3$	
OD	Price	Demand	Price	Demand	Price	Demand	Price	Demand
$v_1 - r_1$	1628	40	1863	68	1863	13	1863	7
$v_1 - r_2$	1488	13	1813	42	1813	7	1813	2
$r_1 - v_1$	1628	35	1948	71	1948	18	1948	4
$r_2 - v_1$	1488	18	1898	34	1898	8	1898	4
Revenue	€ 168.228		€ 405.670		€ 87.158		€ 32.051	
Total	€ 693.107							

Table 3: Basic scenario: Slot allocation and pricing strategy according to same price conditions in booking period  $t$

It is assumed that the booking period of spot market sale is divided into three average time periods  $t = 1, 2, 3$ , where  $t = 3$  represents the greatest time period of booking and offers higher prices for urgent shipper. The demand function coefficients for estimation and variation are determined via using statistical analysis, seen in Table1. The optimization software LINGO 14.0 is used to solve the model. The maximum allotment ( $MA$ ) for contract market sale is kept around 30%, where fixed prices are used for the booking orders of contractual shippers. These shippers have a long term contractual agreement with MTPs

to secure the reservation priority. The rest of slot capacity are allocated according to dynamic pricing strategy. The lowest and highest prices ( $P_{ijt}^{sl}, P_{ijt}^{su}, P_{jit}^{sl}, P_{jit}^{su}$ ) per outward and return trip are calculated according to Equation (3) seen in Table 2, here the value of dynamic price rates should be higher than the rates of contractual shipper.

## FINDINGS AND CONCLUSION

The model is run by using LINGO software, which obtains the total revenue data from operated routes. According to differentiated pricing scenario, seen in Table 2, the price and demand are allocated and the total revenue is calculated as € 699.419. Table 3 shows the basic scenario, where the same pricing strategy is pursued for spot market sale, so that the total revenue is obtained as € 693.107. The comparison of results of two tables showed that the total revenue for multimodal transport operations in this case will increase about 1% by applying dynamic pricing strategy through the proposed model. This provides the evidence that dynamic pricing applications in multimodal freight transport will boost the revenue maximization and the capacity utilization.

In this research, road transport is kept out of the model and the booking period of spot market sales is limited with three time phases. Furthermore, model included only three legs (one port and two hinterland terminals) in order to demonstrate the simplicity of the network system. An extended version of the model will map out a larger network and it can be expanded by applying also road transport and adding additional time phases respond to seasonal demand fluctuations.

## ACKNOWLEDGMENTS

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# **A CLOSED-LOOP SUPPLY CHAIN MODEL WITH PRICE AND SUSTAINABILITY DEPENDENT DEMAND AND COLLECTION RATES**

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## **ABSTRACT**

**Purpose of this paper:** The term sustainability targets economic, environmental and social issues in a system. The application of sustainable practices is a challenge for many businesses today. It is important therefore to establish principles, concepts, and models that capture sustainability (or triple bottom line) and advance the theory and practice in this research area.

Some available models studied environmental and/or social issues in production-inventory and supply chains systems. Few models have considered market demand to be sensitive to both price and quality, with the latter being an aggregated measure of sustainability. Remanufacturing is a fundamental component of sustainable production systems. It saves on virgin material through reuse and repair and on energy as it requires less to remanufacture than to produce a new product. Remanufacturing could be more economical and environmentally sound than recycling, which is energy intensive. It also reduces scrap and waste disposal.

**Design/methodology/approach:** This paper considers a two-level closed-loop supply chain (CLSC) system. Customers return units to the manufacturer (through the retailer) for the purpose of remanufacturing, recycling or scrapping. Factors that affect the sustainability of the system include (but not limited to) carbon emissions released from production and transportation, energy used for manufacturing/remanufacturing, solid waste scrapped, and uncomfortable working conditions.

**Findings:** Numerical results showed that there are optimal values to the number of times to remanufacture a core and the remanufacturing rate that minimizes total costs. The optimal remanufacturing rate may not necessarily be the one that minimizes GHG emissions and increases sustainability. Increasing the number of times to remanufacture a core unit may not necessarily increase the sustainability index; however, it may improve the company's environmental image.

**Practical implications:** An industrial example based on the manufacturing and remanufacturing of starters and alternators in a facility in Ontario, Canada, is presented. Results are discussed to provide researchers and practitioners with valuable information that may explain the effects of various parameters on the sustainability of the system.

## 1. INTRODUCTION

There is ever increasing concern for businesses and organizations to realize sustainability in their role and operations. Their efforts (policies, and procedures) can be slotted as initiatives addressing what is coined as the "triple bottom line" (TBL), i.e., economic, environmental and social performance (Ahi et al., 2016a). Sustainability remains a term with considerable nebulousness in its definition and interpretation, however, the focus is on addressing the triple bottom line by utilizing existing resources to meet current demands without compromising the future's ability to meet its needs (Ahi et al., 2016b).

Research in the application of sustainability in a supply chain context is still in its early stages. In general, the attention has been given to the manufacturing section, and for the most part has focused on the economic and environmental aspects. The amount of work in green and environmentally responsible supply chain modelling have been increasing in recent years. However, quantifying and addressing social aspects is limited (Ahi and Searcy, 2015). There has been limited research regarding the consumer's eagerness to pay a premium for products that have environmental and/or social features (either for features in the product or features in the processes to develop/sell the product), e.g., customers going 'green' or going 'local'. Trade-offs regarding price, demand, profit and sustainability features in supply chains have not been sufficiently studied. Glock et al. (2012) present a model that studies this gap considering a two-level supplier-manufacturer supply chain. However, when considering a model that is environmentally responsible remanufacturing and reverse logistics models cannot be ignored. Further Glock et al. (2012) touch on social factors in sustainability but do not consider this in their model.

Zanoni et al (2014) proposed an integrated production-inventory-marketing model for a single vendor single buyer supply chain, where an investment can reduce the environmental burdens of a production process. The demand is sensitive to the product price and its environmental performance. More recently, Nouria et al. (2016) investigated the impact of the carbon emissions-sensitive demand on decisions relative to the design of a forward supply chain (facility location, supplier selection, production technology selection and transportation mode selection), thus the possible reverse channel has been ignored.

This paper considers a price and quality dependent demand where quality is a measure of sustainability (Glock et al., 2012). The model is a closed-loop two-level supply chain (manufacturer-retailer) based on a real-life industrial example that considers remanufacturing. The mathematics of the proposed model is based on the work of Bazan et al. (2017). The next section presents the model, which includes an industrial example, conceptualization, and the mathematics. This is followed by a numerical example and a conclusion section.

## 2. MODEL

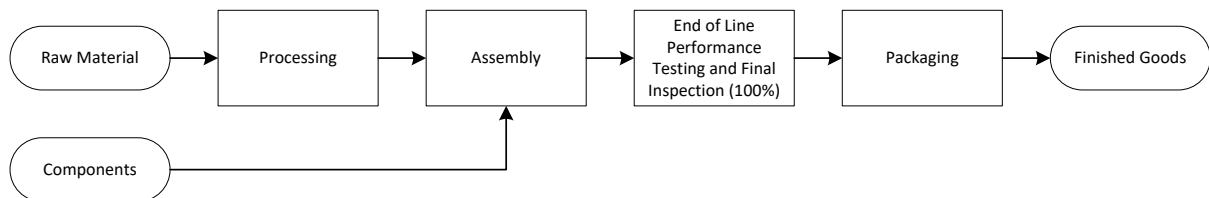
### 2.1 Industrial Example

The remanufacturing of starters and alternators has been an around for years. Our industrial collaborator has been in this business since 1968. Managerial insights from this research could be useful and applicable to many remanufacturing firms across varying industries.

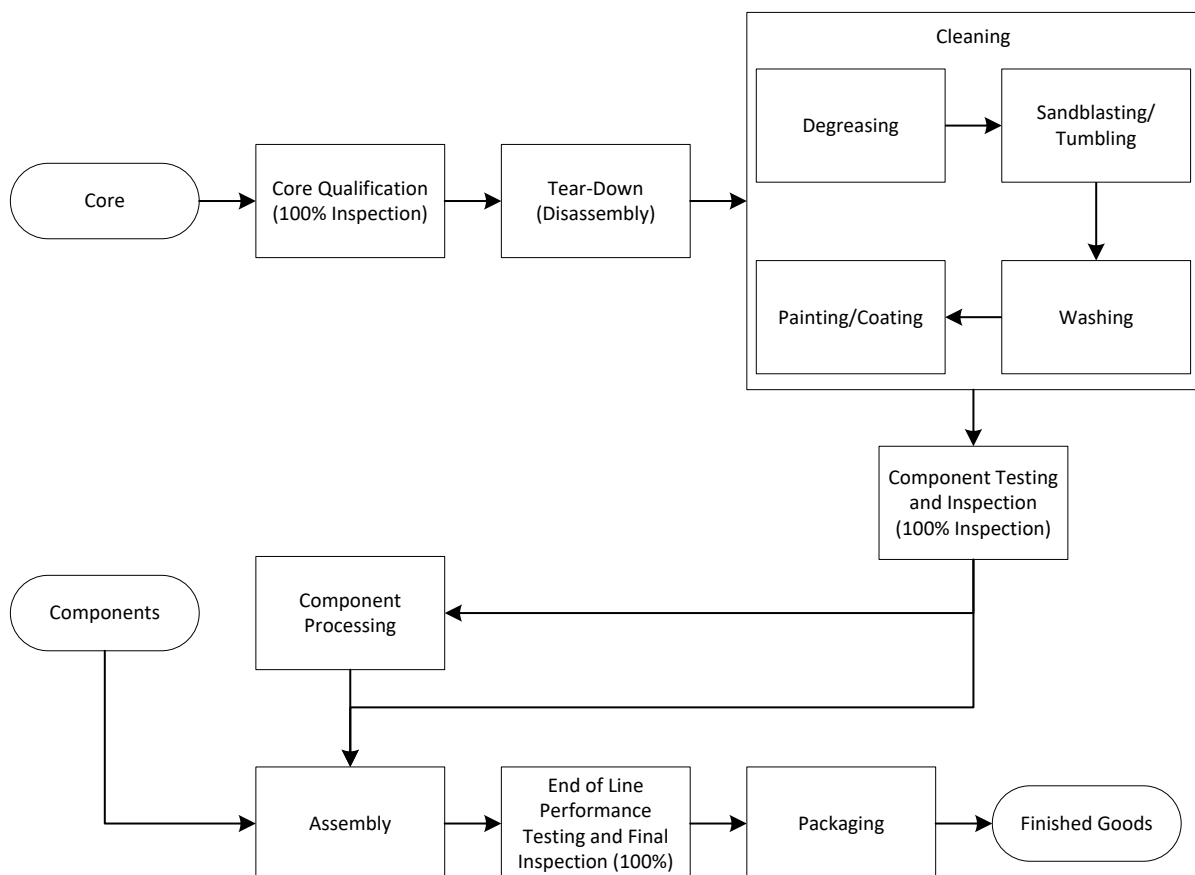
An alternator comprises a housing frame, rotor, stator, regulator, and rectifier. Raw material and components are acquired for winding stators and rotors and assemble the final product. All assembled alternators undergo inspection and performance testing. Fig.1 depicts the manufacturing process.

Alternators are remanufactured from collected 'cores' (items that have reached their useful life). All cores are visually inspected for deformities. The 'tear-down' process is for

disassembling cores into components and storing in separate bins. Cleaning components is costly to the firm and the environment (Seitz and Peattie, 2004). It entails degreasing, sandblasting or tumbling, washing, and painting or coating. Not all disassembled components have to go through all cleaning stages. Some components require less cleaning. Cleaned components are inspected to determine reusable ones. Those that do not pass are scrapped and replaced with new ones. End of line testing and packaging processes are similar to those of new units. The remanufacturing stages are depicted in Fig. 2.



**Fig. 1** Manufacturing stages for new units.



**Fig. 2** Processing stages for remanufacturing.

This specific remanufacturing company sells its products through retailers and warehouses located all over Canada and continental United States. Various coordination schemes are employed depending on the location and type of customer (volume of purchasing).

The literature assumes that remanufacturers will only remanufacture their own products. Our industrial collaborator remanufactures cores of all brands as long as they meet the qualification process. Needless to say, this presents a huge challenge to the remanufacturer as the aftermarket unit may conform to form, fit and function and is

considered interchangeable with the original equipment manufacturer (OEM) unit; however, the internal components of the unit are not interchangeable. The quality of recovered material and components is proportional to the initial price of units.

In conclusion, the industrial example upon which this paper is based represents a complete scenario to highlight environmental and social concerns in a closed-loop supply-chain model. The results from this study could provide managerial insights regardless of product type or industry.

## **2.2 Model Conceptualization**

The model considered is based on the remanufacturing of alternators of a specific type (design) from one manufacturer with a specific level of product quality. The demand provided is only for remanufactured units. There is no demand for an all new unit. Remanufactured units are hybrid containing new and reused components. When a unit is completely new in its entirety to replace demand for a remanufactured unit it is coined in the industry as 'seeding'. This is practiced when there are not sufficient cores available to feed the remanufacturing process. For simplicity, a unit is either remanufactured as a whole or replaced with new as a whole without considering internal components and subassemblies.

Bazan et al. (2017), which was also inspired by this facility, suggest that a vendor-managed inventory with consignment stock (VMI-CS) agreement was a more environmentally conscious coordination mechanism for a supply chain. This paper considers the model, which consists of a manufacturer and a retailer remanufacturing and selling alternators. The manufacturing/remanufacturing process is always in control (no defective items). For privacy and competitive reasons, exact input values are not used. Rather, the values of the input parameters are taken from Bazan et al. (2017).

Glock et al. (2012) present a demand function that is sensitive to both price and quality where quality is considered a sustainability indicator. They only consider scrap and greenhouse gas (GHG) emissions from production. Further, the lack of social factors in the sustainability indicators presented in their model does not complete the picture of a sustainable supply chain model.

In this paper, the sustainability indicator of Glock et al. (2012) is modified to account for energy and social indicators. Bazan et al. (2016) suggest using a scalar objective function. For this model, the sustainability indicators are scaled similar to Bazan et al. (2016) and Glock et al. (2012). For example, the sustainability indicator for energy used for production is the minimum amount of energy that can be used divided by the current amount of energy used based on the current supply chain policy.

Sustainability indicators considered in this paper include the amounts of salvageable units remanufactured, GHG emissions released from production and transportation, energy used for production and time used for production processing (reflecting working conditions). The last quality indicator dealing with amount of time used for production processing is directly related to the internal social aspects of the workers at the facility. Consider a product of complex design with many orifices and heavy paint and accumulation of debris and dirty grease. Such a product will require extensive cleaning processing of which the majority is mainly labour intensive and also expose the workers to fumes and potential hazards from using dangerous cleaning chemicals and use of paint and coating materials. If a product is made of a more robust material that does not require heavy degreasing and/or painting or coating, then management would eliminate some (costly) processing steps and the exposure of the workers to potential safety hazards. Further, complicated units reduce productivity as a result of extended processing times which may be demoralizing for workers and management alike in a competitive marketplace.

### 2.3 Mathematical Model

Adopting the mathematics and notations of Bazan et al. (2017) for the VMI-CS system, the initial decision variables are the batch size, number of remanufacturing batches, number of manufacturing batches (for seeding), and the number of times a product is remanufactured. In Bazan et al. (2017) the objective function is to minimize the total cost of the system. The selling price varies depending on the type of customer and volume of units purchased per year; however, for simplicity, the selling price is considered constant for all customers. This assumption is valid as the inventory system considered utilizes the VMI-CS coordination mechanism that is used by the company for sales to a specific warehouse (single buyer) in the United States. Consequently, the selling price of the unit is a decision variable.

The demand function adopted from Glock et al. (2012) states:

$$d = d(p, q) = a - bp + cq \quad (1)$$

, where  $q$  (non-dimensional) the product quality (sustainability, SI) index,  $0 < q \leq 1$ ,  $p$  is the selling price of unit to end customer (\$/unit),  $a$  is maximum demand (unit/yr), and  $b$  [unit/\$-yr] and  $c$  (unit/yr) are the elasticities of price and quality, respectively. The sustainability index is represented by (El Saadany et al., 2011):

$$q = SI = w_1 SI_S + w_2 SI_W + w_3 SI_G + w_4 SI_E \quad (2)$$

, where  $SI_S$ ,  $SI_W$ ,  $SI_G$ , and  $SI_E$  are the sustainability indicators for solid waste scrap, worker condition, GHG emissions and Energy, respectively. For simplicity, we will assume that all SI values are equally important; i.e.,  $w_1 = w_2 = w_3 = w_4$ .

Maximum scrap is either when no cores are collected ( $\beta = 0$ ) or when collected cores cannot be remanufactured ( $\beta > 0$  and  $\zeta = 0$ ). Either way, maximum scrap is achieved as there is no existing remanufacturing.  $\beta$  is the actual proportion of cores returned for recovery and  $\zeta > 0$  is the number of times an item is remanufactured. The larger the ratio (closer to 1) the more sustainable the system is from a solid waste disposal perspective. Accordingly, (El Saadany et al, 2013; Bazan et al., 2017):

$$SI_S = \beta_\zeta = \frac{\beta - \beta^{1+\zeta}}{1 - \beta^{1+\zeta}} \quad (3)$$

, where an annual investment of size  $C_{inv} = c_{inv}(1 - e^{-\theta\zeta})$  is needed to attain and sustain a desired  $\zeta$  number. This investment will improve the design for disassembly, which will less time to disassemble and better work conditions. This could be as a learning curve function of  $\zeta$ . That is, the more money is invested to extend the life of the product,  $\zeta \rightarrow \infty$ , the better the design for disassembly would be. The relationship may follow a power  $t(\zeta) = t_1 \zeta^{-\lambda}$  and  $t(\zeta) = t_s$  when  $\zeta \geq x$ , where  $t_1$  is the time to disassemble a single core when  $\zeta = 1$ ,  $t_s$  is the standard time to disassemble, and  $\lambda$  is the learning exponent associated with  $c_{inv}$ . Accordingly, (Jaber, 2011):

$$SI_W = \frac{t_s}{t_1 \zeta^{-\lambda}} \quad (4)$$

The minimum amount of GHG emissions that is released by production is achieved if there is no scrap and all collected cores are remanufactured indefinitely, i.e.  $\beta_\zeta = 1$ , and that they are remanufactured at an optimal remanufacturing rate of  $v = b_F^2 / 2a_F$ . Accordingly:



$$SI_G = \frac{c_r - b_r^2/2a_2}{a_r v^2 - b_r v + c_r} \quad (5)$$

, where  $a_r$  (ton.yr<sup>2</sup>/unit<sup>3</sup>),  $b_r$  (ton.yr/unit<sup>2</sup>), and  $c_r$ (ton/unit) are the parameters of the emission function and  $v$ (unit/yr) is the remanufacturing rate (Bazan et al., 2017).

In a similar manner, the energy sustainability index can be written as:

$$SI_E = \frac{C_0 + C_1/v_{\max}}{C_0 + C_1/v} \quad (6)$$

, where  $C_0$ (kWh/unit) and  $C_1$ (kWh/yr) are coefficients of the energy usage function, and  $v_{\min} \leq v \leq v_{\max}$ .

The cost function that includes the classic cost components, which are the setup-order and inventory costs for the Vendor and the Buyer, and it is written as:

$$TrC(Q, n) = (A_1 + n \cdot A_2) \cdot \frac{d}{n \cdot Q} + h_1 \cdot \left( \frac{d \cdot Q}{v} + \frac{(v - d) \cdot n \cdot Q}{2 \cdot v} \right) + (h_2 - h_1) \cdot \frac{Q}{2} \quad (7)$$

, where  $A_1$ (\$/lot) is the setup cost for Vendor,  $A_2$ (\$/order) is the order cost for Buyer,  $h_1$  and  $h_2$  (\$/unit/year) are the unit inventory holding costs for the vendor and the buyer, respectively,  $n$  is the number of shipments and  $Q$  is the shipment size. The non-traditional costs (Bazan et al., 2017) are the carbon emissions,  $CE(v) = c_e d(av^2 - bv + c)$ , and energy usage,  $EU(v) = ed(C_0 + C_1/v)$ , which are added to Eq. (7). The unit cost parameters  $c_e$  and  $e$  are respectively the tax per ton of GHG emissions (\$/ton) and unit energy cost (\$/kWh). Truck load, distance travelled, and fuel and emissions costs could also be added; however, we did not because the distance between the manufacturing facility in Canada and the warehouse in the USA is fixed and the transport is done by a third party logistics so it is treated as a fixed cost. Thus transportation costs have been ignored in this paper, but could be considered in an extended version.

Alternators should cost less to disassemble, clean and remanufacture as more we invest more in the design process. This should improve Labour working conditions. So, the unit cost is estimated as  $c_r(\zeta) = c_0 t_1 \zeta^{-\lambda}$  and the total annual cost is  $LC(\zeta) = dc_0 t_1 \zeta^{-\lambda}$  when  $\zeta < x$  and  $LC(\zeta) = dc_0 t_s$ , otherwise. There is also a disposal cost of unrecovered items of  $DC = c_w d(1 - \beta_\zeta)$ , where  $c_w$ (\$/unit) unit disposal cost. The total cost is, therefore, written as:

$$TC = C_{inv} + TrC(Q, n) + CE(v) + EU(v) + RC(\zeta) + DC \quad (8)$$

, when optimizing Eq. (8),  $v > d$ .

### 3. RESULTS AND DISCUSSION

Consider a remanufacturing facility with the following parameters:  $A_1 = 400$ ,  $A_2 = 100$ ,  $h_1 = 10$ ,  $h_2 = 5$ ,  $a_r = 0.0000003$ ,  $b_r = 0.0012$ ,  $c_r = 1.4$ ,  $c_e = 18$ ,  $v_{\min} = 1200$ ,  $v_{\max} = 2800$ ,  $C_0 = 57.96$ ,  $C_1 = 185744$ ,  $e = 0.0928$ ,  $t_1 = 0.5$ ,  $t_s = 0.1$ ,  $\lambda = 0.3219$  (80% reduction),  $c_0 = 40$ ,  $\beta = 0.8$ ,  $c_w = 6$ ,  $C_{inv} = 5000$ ,  $\theta = 0.2$ ,  $x = 10$ ,  $p = 60$ ,  $a = 1000$ ,  $b = 1$ , and  $c = 100$ .

Table 1 shows the optimal inventory and shipping policy for the vendor and the buyer; i.e.,  $n$ ,  $Q$ , and  $TC$ , for different values of  $\zeta$  (1-5, 10, and 20) and  $v$  (1200, 2000, 2800). The results show that when vendor operates at 2000, the remanufacturing rate that

minimizes GHG emissions,  $TC$  is lowest. This is because savings that the supply chain from reducing GHG emissions,  $CE$ , and energy usage,  $EU$ , are far more than the sum of increases in setup/ordering and holding costs,  $TrC$ , and labour working conditions,  $LC$ , and waste disposal,  $DC$ , costs. The results also indicate that there is an optimal value for the numbers of times to remanufacture a core,  $\zeta$ , and the remanufacturing rate,  $v$ . That is, the lowest  $TC$  value, 28616.5, was recorded for  $\zeta = 10$  when  $v = 2000$  and  $q = 0.9$ . One may ask is there an optimal remanufacturing rate. To answer this, the same example was optimized for  $n$ ,  $Q$ , and  $v$  simultaneously. The optimal policy occurred at  $n = 3$ ,  $Q = 215.2$ , and  $v = 2312.1$  for  $TC = 27976.1$ , where  $q = 0.89$ . We repeated this example for  $\zeta$  equals to 9 ( $TC = 29030$ ,  $q = 0.74$ ) and 11 ( $TC = 28076$ ,  $q = 0.89$ ), and the policies were not optimal. For curiosity, we checked for  $\zeta = 20$  and found  $TC = 28465.5$  and  $q = 0.89$ . This suggest that increasing the manufacturability by an additional 10 times comes at a minimum cost ( $28465.5 - 27976.1 = 489.4$ ) with no improvement to the sustainability index  $q$ . However, a decision to whether this may improve the company's image is to consider.

**Table 1.** Optimal inventory policies for different values of  $\zeta$  and  $v$ .

$\zeta$	$v$	$n$	$Q$	$d(p,q)$	$TC$	$C_{inv}$	$T_rC$	$CE$	$EU$	$RC$	$DC$
1	1200	7	169.7	983.5	38769.2	906.3	3311.3	6939.4	19416.6	4917.4	3278.2
<b>1</b>	<b>2000</b>	<b>4</b>	<b>187.3</b>	<b>1001.7</b>	<b>30625.4</b>	<b>906.3</b>	<b>3744.1</b>	<b>3606.2</b>	<b>14021.2</b>	<b>5008.6</b>	<b>3339.0</b>
1	2800	3	208.9	993.9	31472.0	906.3	3806.7	7012.7	11464.0	4969.3	3312.9
2	1200	7	170.6	988.4	37830.3	1648.4	3310.9	6973.9	19513.2	3953.5	2430.4
<b>2</b>	<b>2000</b>	<b>4</b>	<b>187.9</b>	<b>1006.6</b>	<b>29614.5</b>	<b>1648.4</b>	<b>3750.9</b>	<b>3623.8</b>	<b>14089.7</b>	<b>4026.5</b>	<b>2475.3</b>
2	2800	3	209.4	998.8	30482.3	1648.4	3815.1	7047.2	11520.5	3995.1	2456.0
3	1200	7	171.1	991.0	37617.9	2255.9	3310.6	6992.6	19565.5	3479.1	2014.3
<b>3</b>	<b>2000</b>	<b>4</b>	<b>188.2</b>	<b>1009.3</b>	<b>29365.0</b>	<b>2255.9</b>	<b>3754.6</b>	<b>3633.3</b>	<b>14126.7</b>	<b>3543.1</b>	<b>2051.3</b>
3	2800	3	209.7	1001.4	30243.5	2255.9	3819.7	7065.9	11551.0	3515.6	2035.4
4	1200	7	171.4	992.7	37616.8	2753.4	3310.4	7004.7	19599.5	3176.9	1771.9
<b>4</b>	<b>2000</b>	<b>4</b>	<b>188.4</b>	<b>1011.0</b>	<b>29340.4</b>	<b>2753.4</b>	<b>3757.0</b>	<b>3639.5</b>	<b>14150.9</b>	<b>3235.3</b>	<b>1804.5</b>
4	2800	3	209.9	1003.1	30225.6	2753.4	3822.6	7078.1	11570.9	3210.1	1790.5
5	1200	7	171.6	994.0	37685.3	3160.6	3310.2	7013.5	19624.0	2960.4	1616.5
<b>5</b>	<b>2000</b>	<b>4</b>	<b>188.5</b>	<b>1012.2</b>	<b>29392.5</b>	<b>3160.6</b>	<b>3758.7</b>	<b>3644.0</b>	<b>14168.2</b>	<b>3014.7</b>	<b>1646.2</b>
5	2800	3	210.1	1004.4	30282.2	3160.6	3824.8	7086.9	11585.2	2991.3	1633.4
10	1200	7	174.8	1011.9	37088.6	4323.3	3307.5	7139.9	19977.7	1011.9	1328.4
<b>10</b>	<b>2000</b>	<b>4</b>	<b>190.6</b>	<b>1030.1</b>	<b>28616.5</b>	<b>4323.3</b>	<b>3783.3</b>	<b>3708.5</b>	<b>14419.0</b>	<b>1030.1</b>	<b>1352</b>
10	2000	7	174.8	1030.1	28887.7	4323.3	4054.4	3708.5	14419.0	1030.1	1352.3
20	1200	7	174.9	1012.3	37583.1	4908.4	3307.4	7142.9	19986.0	1012.3	1226.1
<b>20</b>	<b>2000</b>	<b>4</b>	<b>190.6</b>	<b>1030.6</b>	<b>29105.9</b>	<b>4908.4</b>	<b>3783.9</b>	<b>3710.0</b>	<b>14424.9</b>	<b>1030.6</b>	<b>1248.2</b>
20	2800	3	212.2	1022.7	30038.8	4908.4	3856.1	7216.2	11796.7	1022.7	1238.7

One may ask how to increase the sustainability index,  $q$ , for this process. We have investigated this point and found that  $q$  reaches a maximum value when  $\beta$  and the exponent at which the disassembly and cleaning process  $\lambda$  are close to 1 and the remanufacturing rate is  $v = 2000$ . Of course, using new technologies to abate GHG emissions and energy usage will increase  $q$  to a higher value. Including weights  $Waits$  will also impact the value of  $q$ .

#### 4. CONCLUSION AND FUTURE WORK

This paper presented a simple supply chain model that describe a remanufacturing facility in Canada that uses VMI-CS policy with a buyer in the USA. The demand function was assumed to be price and quality (an aggregated measure of sustainability). The results showed that there exist an optimal number to remanufacture a core and an optimal remanufacturing rate that minimizes total costs. The results also implied that adopting new technologies to abate GHG emissions and reduce energy usage are also options.

Investing in product design that may lead to process changes could impact the triple bottom line by not only reducing costs and increasing the amount of remanufactured units, but further reducing/eliminating potentially hazardous processes and working conditions. The model and results of this paper are preliminary. A more complex mathematical model (based on a profit approach) and more in-depth analysis will be provided in an extended version of this work.

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# **DYNAMIC PRICING SERVICES TO MINIMISE CO<sub>2</sub> EMISSIONS OF DELIVERY VEHICLES**

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## **Abstract**

### **Purpose of this paper:**

In recent years, home attended delivery companies have been under increasing legal and administrative pressure to reduce the amount of CO<sub>2</sub> emissions from their delivery vehicles, while the need to maximise profit remains a prime objective. The amount of CO<sub>2</sub> emissions or fuel usage is directly related to travel speed, which is time-dependent. This paper is to develop an approach which helps companies determining price incentives to motivate customers booking a delivery time slot that leads to lower emissions and lower fuel cost.

### **Design:**

In this paper, we study a problem where a company sends engineers with vehicles to customer sites to provide services. Customers request for the service at their preferred time slots through a website or by calling a call centre and the company then needs to allocate the service tasks to time windows and decide on how to schedule these jobs to their vehicles. The cost of an engineer wages is fixed, hence the only varying costs are emission cost and fuel cost. Travel times and travel speed are time-dependent. This means a customer's time-slot choice will influence the overall amount of CO<sub>2</sub> emissions as well as the profit. We propose a new approach to this problem which applies low-emission vehicle scheduling techniques with dynamic pricing to reduce CO<sub>2</sub> emissions and maximise profit. When a customer requests for service with a preferred time slot, the company will provide the customer with different service time-slot options and their corresponding prices. Incentives are included in the prices to influence the customer's choice in order to reduce CO<sub>2</sub> emissions and cost. To help the company in determining the incentives, our approach solves the problem in two phases. The first phase solves time-dependent vehicle scheduling models with the objective of minimising the amount of CO<sub>2</sub> emissions; it calculates least emission cost for each available time-slot option. This is formulated as a mixed integer programming model. The second phase solves a probability based dynamic pricing model to maximise profit, it decides the incentives offered for some time-slot options. A non-linear programming model is formulated. Both models are solved using optimisation software.

### **Findings:**

The approach is tested through numerical experiments. Results are compared with schedules that are generated by always accepting customers' initial preferences. Benefits of applying dynamic pricing have been observed. These include savings in overall CO<sub>2</sub> emissions, as well as improvements in profit.

### **Value:**

Dynamic pricing has been applied to vehicle delivery problem, but the cost is mostly related to delivery time or distance. In this paper, the cost of delivery is the cost of CO<sub>2</sub> emissions. Many researchers also considered reducing CO<sub>2</sub> emissions cost within traditional vehicle routing problem, but they mostly accepted customers' initial choices.

By offering incentives to some available time slots, the service company can further reduce the amount of emissions and, at the same time, achieve more profits.

## 1. Introduction

Since the introduction of legislation and policies such as the Kyoto Protocol in 1998, companies are under increasing pressure to reduce the levels of carbon dioxide (CO<sub>2</sub>) and other greenhouse gas emissions associated with their operations. The main contributor to increased carbon dioxide level in the atmosphere is the burning of fossil fuels, and transportation is a major contributor of emissions. Therefore, to reduce CO<sub>2</sub> emission, it is important to pay more attention to operations related to the road transportation sector. There has been extensive research on vehicle routing problems by both practitioners and academics, but the focus is mainly on minimising the total travel distance or time. More recent research has been driven by green vehicle routing or scheduling problems where the objective is to minimise CO<sub>2</sub> emissions. The travel time of traversing the same pair of customers could be different if the time of travel happens in different time period of the day due to congestion, and so could CO<sub>2</sub> emissions. Since traffic conditions have a significant influence on CO<sub>2</sub> emissions, the amount of emissions is modelled as being time-dependent to capture congestion patterns.

Dynamic pricing has been applied to vehicle delivery problem, but the cost is mostly related to delivery time or distance. In this paper, the cost of delivery is the economic cost of CO<sub>2</sub> emissions. Many researchers also considered reducing CO<sub>2</sub> emissions cost within traditional vehicle routing problem, but they mostly accepted customers' initial choices. In this paper, we develop a time-dependent CO<sub>2</sub> emissions minimisation scheduling model and an improved incentive dynamic pricing model, and use computational studies to simulate the situation of a service delivery company to test the proposed approach. The results show that these models help reduce the total amount of CO<sub>2</sub> emissions and increase profitability.

## 2. Literature Review

### 2.1. Emission Model

There are various emission models that differ in the nature of estimating emission levels and fuel consumptions. The nature of models depends on whether the model is a macroscale model that aggregate total emissions and works as a rough estimate or it is a microscale model that is capable of predicting a relatively more accurate second-by-second emission level. In literature, an agreement has been made that emission level is proportional to fuel consumption, so the models measuring fuel consumptions are equivalent to models measuring emissions directly. A detailed review of existing emission models can be found in Demir, Bektas and Laporte (2011). The emission model applied in this study is a microscale model. It is from NAEI project (Boulter et.al, 2009), which was developed in UK by TRL (transportation research lab). NAEI database are based on a large number of measurements from various programmes conducted over years. NAEI suggests the following emission models:

$$E = (a + bv + cv^2 + dv^e + f\ln(v) + gv^3 + h/v + i/v^2 + j/v^3)x \cdot \text{distance}$$

where  $a-j$  and  $x$  are vehicle category and pollutants type specified coefficients. The formulation could also be adjusted for road gradient and vehicle load.

### 2.2. Time-dependent Green VRP

Some previous works on Green VRP assume that vehicles can travel at an emission-minimising speed or free-flow speed, but in real life vehicles must travel at the speed of traffic, especially in urban areas, where speed is a variant and time-dependent. In literature, some studies built up a speed or transit times lookup table/profile for each time period in a day (Figliozzi(2010)). In this paper, we also built up a speed profile.

Figliozzi (2010) first introduced the emissions vehicle routing problem (EVRP) with time-dependent travel speeds, which typically represents varying traffic conditions. A mixed integer programming problem was formulated with two objectives: minimising number of vehicle and minimising emissions cost. Time-dependency of speed was modelled through

discretizing the planning horizon into five time intervals and each time interval is associated with a mean speed value, which is artificially generated to reflect different traffic conditions. Emission cost was calculated as an estimated market price of CO<sub>2</sub> emissions. This market price may not be accurate as it is hard to predict the economic price of emissions, unless emissions tax is officially launched. In Franceschetti et al. (2013), they used fuel price to represent emission price.

Qian and Eglese (2016) studied a CO<sub>2</sub> emission minimisation vehicle routing problem with time varying travel speed. Test cases were generated on a London road map with real traffic data, including speed data for each road. Also, there are multiple possible road links that connect two customers' sites like in real life, so path selection will be part of the decision problem. They treated travel speed as a decision variable, ranging up to current maximum traffic flow speed on the link travelled. They showed that with path selection and speed optimisation, 2-3% emissions are saved comparing with always using fastest path and traffic flow speed. However, if in the speed range emissions level is not very sensitive to speed change, setting travel speed to traffic flow speed will give a good solution as well.

### **2.3. Demand Modelling in VRP**

Cleophas and Ehmke (2014) defined demand modelling in VRP as value based demand modelling which differed from traditional demand management as the cost of delivery varies. They studied a combination problem of cost minimal routing and value-based order acceptance techniques. They did not study the pricing of orders. Yang et al. (2013) investigated dynamic delivery pricing problems in e-fulfilment of an online grocery store. The cost of each delivery is the travel cost, and the demand of customer is modelled using a multinomial logit choice model. In this paper, we will use a different customer demand model. Among the existing literature, the problem closest to the one in this paper is addressed by Campbell and Savelsbergh (2006). These authors consider the problem of online groceries delivery, where customers come with their preferred time windows and use a two stage process to reduce travel costs; the first stage solving a vehicle routing and scheduling problem and the second solving a dynamic pricing problem. Their paper offers insights into the use of incentive schemes to substantially reduce delivery costs, considering a distance problem. However, the amount of incentives offered is highly restricted to customer's initial probability of choosing one time slot.

### **3. Problem Description and Solution Approach**

We study a problem where a company sends engineers to customer sites to provide maintenance and installation services in a confined area. The distances among customer sites and the depot are all close and may be considered roughly the same, e.g. 5km. The company divides each day into several time windows. Typically each customer makes a request for the service through a website or telephone. The customer order normally comes with a preferred time window for the service to start. Instead of simply accepting the customer requested time window, the company can provide the customer with a number of service time-window options and their corresponding prices. Incentives are included in the prices to influence the customer's choice to help the company ensure a schedule which reduces CO<sub>2</sub> emissions. Traffic conditions have a significant influence on CO<sub>2</sub> emissions, and an average speed profile was constructed based on real travel information in London, UK. Based on the traffic pattern of the area, a day is divided into a number of time slots (1 hour) such that the emission level within a time slot can be considered the same.

In this paper we deal with a more dynamic nature of demand, where at the start of the schedule planning horizon, the planner has an initial set of previously accepted jobs with their agreed time windows. Meanwhile, new customers will arrive in the system dynamically each with an original preferred time window for service. At the time of each new customer arrival, the problem is to determine the incentives and hence the prices for

the service for different time windows. Once the customer selects a service time window based on this price information, the schedule is updated to include both the new task and the existing tasks that are not performed yet. The overall objective is set to maximise the expected profit which is defined as the standard service price minus the expected incentives and the emission cost, aiming to reduce the amount of CO<sub>2</sub> emissions as well as increasing profit.

We propose a different approach to this problem which applies both low-emission vehicle scheduling techniques and dynamic pricing. An initial schedule of the vehicles is constructed based on information of the initial set of tasks. Whenever a new customer order arrives with an original time-window preference, prices for the task to be performed in different time windows are determined and presented to the customer; the new task will be scheduled to start in the time window that the customer selects based on the price information. The actual start times and the vehicles for the unserved existing tasks may be changed in the schedule in order to minimize the emission cost. However, their agreed time windows will need to be satisfied in the updated schedule. Therefore, we need to make both pricing and scheduling decisions each time a new customer order arrives. We propose to make these two decisions in two phases.

The first phase deals with the scheduling decisions. We solve several possible scheduling problems each assuming the new task being allocated to a different time window. The solution of each problem provides a schedule with minimised emission costs with the new task scheduled to start in the corresponding time window. The second phase makes pricing decisions using the emission costs obtained in the first phase. Based on the new customer's original preference, the probabilities for the customer to choose each time window are estimated. The sensitivity of these probabilities with price changes is assumed to be known. The pricing problem in the second phase can then determine the incentives/prices for each time window so that the expected profit is maximised. Once the customer selects a time window based on the pricing results, the corresponding schedule obtained in the first phase can be used as the current schedule. Within this framework the models are used to help the planner to respond to customer requests and schedule the tasks. At the time a new customer arrives, some existing tasks may have started but are not completed, such tasks have to be continued without change. Until the completion time of such a task, the vehicle assigned to this task will not be available.

### **First Phase: Green Vehicle Scheduling Model**

The first phase model schedules or reschedules all the service tasks on hand to the vehicles with the objective to minimise the emission cost. At the start of the planning horizon, the tasks considered in the model are the initial set of customer orders, while the tasks in each of the subsequent models include the new customer order and the unserved existing tasks. Each task has a required time window for the service to start. The time window for the new task is the assumed possible time window.

We assume the company's business is in a confined geometric area, and the distance between each customer sites is similar and assumed to be 5km. The whole planning horizon is  $[0, T]$ , where  $T=1000$  is the last time a new customer can be served. This planning horizon can be converted to real life time, with 200 represents roughly 2 hours. We divide the whole planning horizon into several equal time slots. Each time slot has an average amount of emissions, which is calculated using NAEI formula, 5km travel distance and speed profile constructed based on real life data. [1.680kg, 2.741kg, 4.179kg, 2.741kg, 1.680kg, 2.741kg, 4.179kg, 2.741kg, 1.680kg, 1.680kg] presents a profile of CO<sub>2</sub> emissions over the planning horizon based on different levels of travel speed across the day. The emission costs are assigned based on this times current fuel price (e.g. £1.371/kg).

### **Notations**

$i, k$ : index of customers;

$j$ : index of vehicles;  
 $N$ : total number of customers;  
 $V$ : total number of vehicles available;  
 $M1$ : a big positive number;  
 $T$ : end time of the planning horizon;  
 $n$ : total number of time slots in the planning horizon, the length of each slot is  $T/n$ ;  
 $b_i, e_i$ : beginning and ending times of the required time window in which a vehicle must arrive to customer  $i$ ;  
 $s_i$ : service time needed for customer  $i$ ;  
 $\tau_t$ : travel time between any two sites;  
 $a_j$ : the time when vehicle  $j$  becomes available;  
 $c_t$ : emission cost for a trip in time slot  $t$ .  
 $C_i$ : emission cost of serving customer  $i$ ;  
 $u_i$ : time point a vehicle starts travelling to customer  $i$ ;  
 $w_i$ : time point the service at customer  $i$  starts;  
 $x_{ij} = \begin{cases} 1, & \text{if customer } i \text{ is allocated to vehicle } j, \\ 0, & \text{otherwise} \end{cases}$ ;  
 $y_{ik} = \begin{cases} 1, & \text{if customer } i \text{ is served before customer } k \text{ by the same vehicle,} \\ 0, & \text{otherwise} \end{cases}$ ;  
 $z_{it} = \begin{cases} 1, & \text{if traveling to customer } i \text{ starts in time slot } t, \\ 0, & \text{otherwise} \end{cases}$ ;  
 When a new customer requests service, the scheduling problem needs to be re-solved.

This is formulated as follows.

**Minimise**  $\sum_{i=1}^N C_i$

**Subject to**

$$C_i \geq c_t + (z_{it} - 1)T, i = 1, \dots, N; t = 1, \dots, n \quad (1)$$

$$\sum_{j=1}^V x_{ij} = 1, i = 1, \dots, N \quad (2)$$

$$\sum_{t=1}^n z_{it} = 1, i = 1, \dots, N \quad (3)$$

$$y_{ik} + y_{ki} = 1, i, k = 1, \dots, N, i \neq k \quad (4)$$

$$b_i \leq w_i \leq e_i, i = 1, \dots, N \quad (5)$$

$$w_i \geq u_i + \tau_t + (z_{it} - 1)T, i = 1, \dots, N; t = 1, \dots, n \quad (6)$$

$$w_i + s_i \leq u_k + M1(3 - x_{ij} - x_{kj} - y_{ik}), i, k = 1, \dots, N; j = 1, \dots, V \quad (7)$$

$$u_i \geq (t - 1)(T/n)z_{it} + T(z_{it} - 1), i = 1, \dots, N; t = 1, \dots, n \quad (8)$$

$$u_i + \tau_t \leq t(T/n) + T(1 - z_{it}), i = 1, \dots, N; t = 1, \dots, n \quad (9)$$

$$x_{ij}, y_{ik}, z_{it} \in \{0, 1\}, i, k = 1, \dots, N; t = 1, \dots, n \quad (10)$$

$$w_i, u_i \geq 0, i = 1, \dots, N \quad (11)$$

The objective is to minimise emission cost. Constraints (1) define the emission cost of customer  $i$ . Constraints (1) specify that each customer is served once and by only one vehicle. Constraints (2) ensure that travelling to each customer  $i$  starts in only one time slot. Constraints (4) indicate the sequence of serving customers, a sub-tour elimination constraint. Constraints (5) ensure that the time window requirements of each customer must be satisfied. Constraints (6) require that service start time must allow for travel time between customers. Constraints (7) will take effect when  $x_{ij} = 1, x_{kj} = 1, y_{ik} = 1$ , which means customers  $i$  and  $k$  are both served by vehicle  $j$ , and customer  $i$  is served before customer  $k$ . Under this circumstance, the constraint ensures that the vehicle can start travelling to customer  $k$  only after it completes serving customer  $i$ . Constraints (8) to (9) identify the start and end time slot indexes. These help us to link continuous variable  $u$  and binary variable  $z$ . Constraints (10) and (11) are binary and non-negativity constraints.

## Second Phase: the Pricing Model

When a new customer arrives with an initial preferred time slot, the planner will compute a price menu for each available time windows. Incentives are given to time windows which produce lower emission; with the aim of shifting the customer's demand. The incentive pricing model is adopted from Campbell and Savelsbergh (2006), whose model uses a distance cost function compared to the emission cost function used in the current



paper. The emission cost for each time slot is calculated from the output of the first phase green vehicle scheduling model. These are used in the pricing model to decide which windows should receive incentives and the amounts of incentives. We also aim to improve on their model in two ways. The amount of incentives they offer is highly restricted to the lowest initial probability of choosing one time slot and the time windows which will be given incentive are pre-determined, refer to Campbell and Savelsbergh (2006) for more details. Our model mends their model by imbedding the selection of time windows into the optimisation and incentives are not restrictive by the lowest initial probability. In line with Campbell and Savelsbergh (2006), we assume that the company has knowledge of the likelihood of a customer selecting a specified time slot and the effect of price change on the customer's buying behaviour. With the advent of the internet, it is reasonable to assume that businesses have access to vast historical data about customers. Online grocery shopping and delivery companies have developed interfaces for customers to book a service and monitor their purchasing behaviour as well as their reactions to incentives or discounts.

### Notations

$h$ : index of time windows;

$O$ : sets of all time windows;

$p^h$ : probability of the customer choosing time window  $h$  if no incentives are offered;

$C^h$ : additional emission cost of including the customer into an optimised schedule;

$r$ : revenue from the current customer;

$\beta$ : price sensitivity parameter;

$B$ : maximum incentive that may be applied to time window  $h$ ;

$M2$ : a large positive number.

$I^h$ : incentive price for time window  $h$ ;

$z$ : amount of probability reduced;

$qu^h$ : the probability that time window  $h$  with incentive will be chosen by the customer;

$qv^h$ : the probability that time window  $h$  without incentive be chosen;

$$\alpha^h = \begin{cases} 1, & \text{if } I^h \geq 0 \\ 0, & \text{if } I^h = 0' \end{cases}$$

$$X^h = \begin{cases} 1, & \text{if } p^h - z > 0 \\ 0, & \text{if } p^h - z \leq 0 \end{cases}$$

The pricing model is formulated as follows:

**Maximise**  $\sum_{h \in O} (r - C^h - I^h) * qu^h + \sum_{h \in O} (r - C^h) * qv^h$

**Subject to**

$$0 \leq I^h \leq B * \alpha^h, \forall h \in O \quad (12)$$

$$qu^h \leq p^h + \beta * I^h, \forall h \in O \quad (13)$$

$$qu^h \geq p^h + \beta * I^h + (\alpha^h - 1), \forall h \in O \quad (14)$$

$$qu^h \leq \alpha^h, \forall h \in O \quad (15)$$

$$\alpha^h + qv^h \geq p^h - z, \forall h \in O \quad (16)$$

$$qv^h \leq p^h - z + 1 - X^h + \alpha^h, \forall h \in O \quad (17)$$

$$p^h - z \leq X^h + \alpha^h, \forall h \in O \quad (18)$$

$$qv^h \leq X^h + \alpha^h, \forall h \in O \quad (19)$$

$$qv^h \leq 1 - \alpha^h, \forall h \in O \quad (20)$$

$$\sum_{h \in O} (qu^h + qv^h) = 1 \quad (21)$$

$$I^h \geq \frac{1}{M2} + M2 * \alpha^h - M2, \forall h \in O \quad (22)$$

$$\alpha^h \leq 2 * M2 * I^h, \forall h \in O \quad (23)$$

$$qu^h, qv^h \geq 0, \forall h \in O \quad (24)$$

The objective is to maximise expected profit. The first part of the objective function represents the expected profits from the time windows which are given incentives and the second part represents the expected profits from the windows which do not receive any incentive. Constraints (12) restrict the incentive to be in range  $[0, B]$ . Constraints (13) - (15) calculate the adjusted probability,  $qu^h = p^h + \beta * I^h$  for all  $h$  receiving incentives. If time window  $h$  does not receive an incentive,  $qu^h = 0$ . If a time window

does not receive incentive, the probability of the customer choosing it will reduce, this is represented by constraints (16) - (20). If the adjusted probability of a time window which does not receive incentive is greater than zero, i.e.,  $p^h - z > 0$ , then the adjusted probability,  $qv^h = p^h - z$ , otherwise,  $qv^h = 0$ . Constraints (21) ensure that the probabilities for all time windows sum to one. Constraints (22) and (23) indicate that if a time window receives an incentive, the amount of incentive is greater than zero. Constraint (24) indicates that probability is greater or equal to zero.

### Numerical Experiments

The green scheduling and pricing approach is tested using numerical experiments. In the experiments, the whole planning horizon is set to be one day. For convenience we choose a time unit such that the length of this planning horizon is 1000. The whole period is divided into five equal time windows that customers may choose for their requested service to start. Reflecting the congestion conditions, the profile of emission cost is expressed using ten time slots. The solution approach described in the last section is implemented simulating customer arrivals and the service operations for the whole planning horizon. We generate an initial set of customers at the beginning of the day and simulate subsequent customer arrivals using Poisson process. For each customer arrival, a preferred time window is randomly generated. The probability for the customer accepting each available time window is calculated using a triangular distribution with the preferred time window as the mode. The green scheduling model is run to obtain the emission cost for the task being performed in each available time window. The pricing model is then run to decide the incentives given for each of these time windows. The time window of the customer's final choice is generated according to the probabilities in the result of the pricing model.

We compare our approach with the green scheduling method without incentives. The green scheduling method is implemented using the same simulation framework. In this method the scheduling model is applied to schedule each customer's task always to their preferred time window. We assume there is an initial set of 10 customers at the start of the planning horizon, and the customer service time is a random value in the range of [33, 90]. We simulate the customer arrivals using a Poisson process with mean inter-arrival time of 50, and therefore on average there are approximately 20 new requests per day. We generate 30 set of customer arrival times and their initial time windows, each for one day. Each set of data is called a scenario. Because each customer's final choice is uncertain, the result may be different in different runs even for the same scenario. Therefore, we run each of these 30 scenarios 10 times and calculate the average emissions and profit. We assume each customer will bring revenue of 30, which is about 10 times the amount of emissions cost, as we also need to cover other cost to make profits. The profit is calculated by the revenue minus incentives and the emissions cost. We compare the two methods in terms of the CO<sub>2</sub> emissions cost and the profit. The results are shown in Table 1.

Scenarios	No. of New Customers	Ratio of existing customers	CO <sub>2</sub> Savings (%)	Improvement in profits (%)
1	20	0.33	26.752	3.373
2	15	0.40	1.607	0.123
3	14	0.42	3.955	0.362
4	24	0.29	24.845	3.278
5	22	0.31	3.856	0.177
6	21	0.32	4.039	0.346
7	21	0.32	4.436	0.221
8	22	0.31	27.040	3.435
9	20	0.33	26.980	3.473

10	12	0.45	4.164	0.312
11	17	0.37	1.926	0.173
12	14	0.42	2.326	0.113
13	22	0.31	0.694	0.201
14	15	0.40	3.789	0.351
15	21	0.32	26.069	3.360
16	21	0.32	3.210	0.086
17	18	0.36	1.863	0.166
18	18	0.36	2.636	0.054
19	18	0.36	43.107	7.658
20	23	0.30	0.349	0.032
21	26	0.28	24.879	2.956
22	20	0.33	1.683	0.110
23	15	0.40	0.235	0.015
24	16	0.38	2.436	0.161
25	24	0.29	25.399	3.264
26	22	0.31	5.936	0.584
27	17	0.37	1.436	0.046
28	18	0.36	2.767	0.219
29	18	0.36	2.728	0.165
30	19	0.34	7.104	0.711
<b>Average</b>		<b>0.35</b>	<b>9.608</b>	<b>1.184</b>

Table 1 Comparing CO<sub>2</sub> emissions and profits.

## Conclusions

The results demonstrate the effects of incentives on both the emissions cost and the profit generated. Our incentive model reduces the CO<sub>2</sub> emission cost by 9.608% on average, compared to a green vehicle scheduling method without incentive. Meanwhile the average profit increases by 1.184%. The average results show that the incentive pricing model can both increase profits and reduce carbon dioxide emissions significantly.

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# **SUSTAINABLE PROCUREMENT STRATEGY: A CASE STUDY OF A CO-OPERATIVE GROCERY RETAILER IN THE UK**

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## **ABSTRACT**

The procurement process as the starting point of a supply chain plays a key role in determining the overall performance of any retailer. While larger retailers are more likely to either encourage or pass on their responsibilities to their upstream suppliers to participate in sustainability improvements, small-scale cooperative retailers and specialist businesses are generally considered leaders in the field of sustainability. However, there is a lack of research measuring the level of disclosure related to sustainable procurement strategies in such organisations. Thus, this study aims to 1) develop a framework for measuring sustainability in terms of procurement in retail grocery sector 2) assess sustainability performance of the case organisation by examining their sustainable procurement strategies and practices including their supplier selection criteria. This study adopts the content analysis method by analysing both qualitative and quantitative data. Research findings show that most of the focus of sustainable procurement in the case organisation is on environmental policies and employee welfare while lesser attention has been given to quality control, seasonal food and donation. The findings of this study will assist policy makers, practitioners and academics acquire a deeper understanding of sustainability performance in the grocery industry and will delineate how to improve retailing firms' sustainability in the sourcing process.

## **INTRODUCTION**

Currently, the food supply chain is criticised on account of its negative environmental (Styles et al., 2012) and social (Busta and Kennedy, 2011) impacts and has been blamed for problems such as ecosystem disruption, energy waste and public lifestyles to a certain degree. The critical role of retailers in driving environmental improvement and social responsibility is emphasised owing to their size and density in local marketing (Chkanikova, 2015). In effect, the market in most European countries, including the UK is moving towards oligopoly, where a few (three to five) supermarkets occupy the majority of food marketing activities and represent the focal companies in the whole supply chain (Gereffi et al., 2005). The procurement process as the starting point of a supply chain plays a key role in determining the overall performance of any retailer (Zimmer et al., 2010). Many researchers claim that due to their focal position in dispersed supplier networks and external pressures from consumers and governments, large retailers are more likely to either encourage or pass on their responsibilities to their upstream suppliers to participate in sustainable improvements (Kotzab et al., 2011).

Robinson (2010) and Styles et al. (2012) are among a few to examine the sustainable procurement (SP) practices of some of the European retailers. According to Styles et al. (2012), leaders in the field of SP improvements are generally small-scale cooperative retailers and specialist businesses. However, there is a lack of research attempting to measure the level of disclosure related to sustainable procurement strategies in such organisations.

Moreover, grocery retail sector contributes a significant proportion of the national GDP. This is evidenced by the fact that the Fortune 500 in 2011 featured 45 retail companies. This sector is also the UK's largest private sector employer with 2.9 million employees and accounts for more than 16% of national employment. Furthermore, retail sales reached a total value of £321 billion in 2015, accounting for 9% of all UK business. However, this sector is often perceived as both eco-friendly and environmentally destructive, which means it offers an intriguing case study upon which to examine CSR disclosure in the context of retail. In food channels, competition is rather fierce and the top retailers (Wal-Mart, Tesco, Carrefour, Costco) are constantly seeking new breakthroughs in sustainable practices. Retailer cooperatives, on the other hand, may take a different approach by offering a platform for more specialised goods that appeal to niche as opposed to mass-market consumers and integrating local food networks based on mutual trust to achieve a win-win situation. Given the relatively limited number of articles exploring SP in specialised retailers, a significant opportunity exists to examine the disclosure of SP strategies and practices in coop groceries using secondary data analysis. Therefore, overall aim of this research is to investigate SP strategies and practices in co-operative groceries.

The specific objectives are to 1) develop a framework for measuring sustainability in terms of procurement in retail grocery sector 2) assess the disclosed SP performance of the case organisation by examining their SP strategies and practices including their supplier selection criteria.

The paper is organised as follows. The next section reviews the literature on sustainable procurement practices/strategies and indicators to measure sustainability performance in retail sector with final section focusing on drivers and barriers for sustainable procurement practices in retail sector. The research methodology briefly presents the method used for data collection and analysis. The following section presents findings including the conceptual framework generated as part of this study. The paper closes with conclusions, limitations and areas for future research.

## **LITERATURE REVIEW**

### **State-of-the-art literature on sustainable procurement retail industry**

Given that the standards and regulations across each industry segment are different, it is essential to assess the literature in the given industry. A total of 143 peer-reviewed articles were examined on the sustainable procurement practices from 1990-2016. 18 out of 143 articles focused on food and retail sector (e.g. Rimmington et al., 2006; Pullman and Dillard, 2010; Saunders and Bromwich, 2012; Aggarwal and Srivastava, 2016). This sector also attracted attention due to the potentially negative environmental impacts of the food industry (Belal, 2002; Styles et al., 2012; Wiese and Toporowski, 2013). A few research were focused on co-op model and were predominantly covering only their environmental performance (Baranchenko and Oglethorpe 2011), including local supply network model (Hingley, 2010). Negative perspectives on this form of business are also identified as Davies and Burt (2012) argue that the failure rate of supply networks in coops has been very high as such businesses have been unable to convert their early-mover advantages into sustainable retail networks. However, none of these articles aimed to evaluate the level of sustainability in procurement strategies and practices in coop groceries. Although these food retailers claim to operate their business and supply chain management in a sustainable way, it is unclear whether or not they are fulfilling these claims in practice.

### **Assessing sustainable procurement performance in retail sector**

Zimmer et al. (2015) analysed and reviewed scientific publications on sustainable supply management between 1997 and 2014 and proposed that articles related to supply management activities mainly focus on three aspects, including the supplier selection process, the development of sourcing strategies and triggers and difficulties in implementing SP. Azadnia et al. (2014) highlight how supplier selection is a multi-stage

process that is generally initiated by determining the demands and requirements before specific criteria are set. As to the development of SP, 'strategy', 'transparency' and 'impact on performance' are three popular areas in this field. Similarly, Styles et al. (2012) assess the supply chain strategies, supply chain practices and sourcing performance of 25 major European retailers. Based on previous literature, this research will assess the performance of SP in coops from three perspectives including the disclosure of SP strategies, the level of sustainability requirements in supplier selection criteria and the disclosure of SP practices. Based on the work of Genovese et al. (2010), the selection of sustainable suppliers is a process undertaken by firms to determine the most ideal suppliers from a range of prospective options. SP strategies can reflect where a firm considers the sourcing function in a sustainable way while SP practices indicate what they have achieved in the field of SP. The gap between SP strategies and SP practices contributes an insight into the genuine status of SP in these organisations. Therefore, each aspect of measuring SP performance in coop groceries will be examined from economic, environmental and social dimensions according to the triple bottom line, which is widely accepted by many supply chain researchers (e.g. Reuter et al., 2010; Tate et al., 2010). With regards to difficulties in the implementation process, both internal and external aspects are discussed. The matrix for measuring the sustainability of procurement performance is shown in Figure 1.

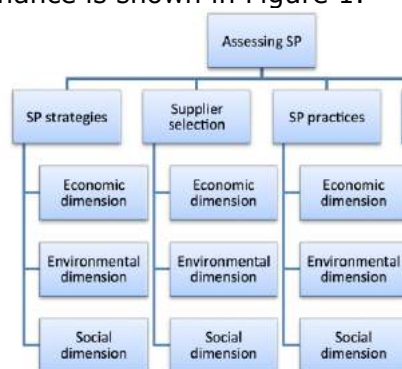


Figure1. The framework of assessing sustainable procurement performance in grocery retailers

### Supplier selection criteria in food retail industry

According to Elkington (1998), sustainability is often regarded as a consideration of economic, environmental and social concerns. A large number of companies now acknowledge the significance of sustainability in the field of purchasing management and the integration of all three elements into the triple bottom line approach is required when selecting suppliers in order to gain or maintain a competitive edge. (Dai and Blackhurst, 2011; Azadnia et al., 2014). An overview of the ten most important sustainable supplier selection criteria in the retail industry from the existing literature is given in the following section and the synthesis is presented in Table 1.

Table 1. Top 10 sustainable supplier selection criteria in food retail industry

Criteria	Sub-criteria	Other keywords	References
Economic	Cost	Ordering cost Purchasing cost Holding cost	Humphreys et al. (2003); Rimington et al. (2006);
	Price		Awasthi et al. (2010);
	Quality	Product quality certificates labelling	Bai and Sarkis (2010);
	Delivery	On-time delivery transportation	Baskaran et al. (2011)
	Lead time		Dai and Blackhurst (2011);
	Loyalty	After sales services On-time payment	Amindoust et al., (2012);
	Rejection ratio		
	Investment of R&D		
	Financial situation		
	Public image	Reputation	

<b>Environmental</b>	Environmental management system (EMS)	Environmental policies ISO14001	Govindan et al. (2013); Azadnia et al. (2014); Zimmer et al. (2015).
	Resource consumption	Energy consumption	
		Water consumption	
	Pollution	Chemical pollutant, Air emission pollutant, GHG	
	Environmental certificates	Red Tractor, LEAF, Organic, Marine Stewardship Council or equivalent	
	Recycle	Disassembly/Reuse	
	Animal welfare	Biodiversity	
	Green packages		
	Waste	Disposal/Water waste/Solid Waste	
	Green technology	Clean technology	
	Eco-design		
<b>Social</b>	Training	Education	
	Employee safety	injury	
	Retire		
	Recruit	Job opportunity	
	Wage	Employee contract	
	Employee health		
	Discrimination	Female/ Race	
	Child labour		
	The free choice of occupation	Freedom	
	Working condition	Workplace	

In order to assess the sustainability of potential suppliers, related criteria and sub-criteria were reviewed at this stage. As can be seen from Table 1, economic factors primarily include traditional elements such as cost, quality and delivery time (Dai and Blackhurst, 2011; Govindan et al., 2013). Particularly, an increasing number of retailers now take the long-term development of suppliers into account, such as after sales service, technology availability and investment in innovation (Govindan et al., 2013). In terms of environmental factors, given the substantial impact of the retailing industry on the environment, the evaluation of the environmental performance of suppliers has been highlighted (Awasthi et al., 2010). Corporations tend to motivate their suppliers to improve their environmental score by generating environmental requirements (Azadnia et al., 2014). This point has been echoed by Caniëls et al. (2013) who suggest that requirements from buyers have a positive influence on supplier participation in green initiatives. Although Caniëls et al.'s (2013) study was focused on the automotive industry rather than the retail industry, the authors assert that buyer requirements in particular exert a powerful effect on almost all small and medium-sized suppliers. Most research studies in the domain of qualifying sustainable supplier selection place emphasis on environmental and economic dimensions, while with increased pressure from the general public, some scholars have also begun to devote their attention to the corporate social responsibility aspect (Bai and Sarkis, 2010; Amindoust et al., 2012; Govindan et al., 2013). When it comes to social criteria, Bai and Sarkis (2010) contend that social metrics for supplier selection decisions should be sorted into internal criteria (employment practices) and external criteria (stakeholders influence). In another study, Govindan et al. (2013) adopt employment practices, employee safety and local community influences to address a real-life supplier selection problem, indicating that these criteria are the most practical. The results of sustainable supplier selection criteria are regarded as the most used factors for assessing the performance of potential suppliers in the retail industry. Thus, these criteria will be examined in more detail with regard to the case company.

### The principles of SP strategies and practices

With regard to the retail industry, there is growing strategic importance placed on understanding sustainable sourcing, as retailers now widely acknowledge that the traditional view of procurement is largely ineffective when attempting to deploy sustainable practices. In addition, companies that do not perform well in terms of social,



economic or environmental factors will likely experience a decline in market image and a reduction in sales to an extent far greater than their suppliers (Schneider and Wallenburg, 2012). Therefore, both nominal definitions and operational principles of sustainable procurement will be discussed in this section.

When referring to the concept of sustainable procurement, primeval literature mainly explores either social (Min and Galle, 1997; Krause et al., 1999; Cooper et al., 2000; Eltantawy et al., 2009) or environmental (Green et al., 1996; Carter et al., 1998; Walton et al., 1998) areas. For example, Green et al. (1996) used the term “green purchasing” to refer to environmental-friendly considerations in industrial purchasing and supply management. Eltantawy et al. (2009), on the other hand, accentuated “meeting societal norms” and “legally required” when managing the material flow. Furthermore, an increasing number of scholars (Maignan et al., 2002; Roberts, 2003; Walker and Brammer, 2009) propose somewhat comprehensive concepts combining both aspects but ignore economic performance in sourcing activities, which is a basic prerequisite in the market economy. Taking Walker and Brammer’s (2009) definition as an example, sustainable procurement is required to ensure a healthy and fair society and the well-being of the environment. Pagell et al. (2010), on the other hand, present an assessment measure of sustainable sourcing based on a business’ impacts on people, profits, and the environment. Accordingly, the term “triple bottom line” is now widely used in many sustainability research studies (e.g. Reuter et al., 2010; Tate et al., 2010). According to this, sustainable procurement is defined as providing good economic value at competitive costs, meeting high environmental standards, and enforcing social values and standards. In this study, the researcher also considered sustainable procurement from three aspects, namely, economic, environmental and social aspects.

As reflected in the variety of definitions, sustainable procurement is a broad and rather complicated process. It also comprises a number of factors that are interconnected, such as purchasing, the supply process, the environment, society, economic development, corporate governance and value for money. According to the definitions and standards offered by different authors and authorities (see Table 2), this study subdivides specific terms into economic, social and environmental categories and each category have ten most important principles, which will create a conceptual qualification in assessing the sourcing function’s sustainability. This result will be utilised to evaluate the disclosure of sustainability in cooperative groceries’ procurement function.

*Table.2 The principles of SP strategies and practices*

Category	Principles	Other keywords	References
<b>Economic sustainability</b>	Waste	Food waste	Walker et al. (2008);
	Cost		Darnall et al.
	Transparency	Open-book accounting	(2008);
	Innovation		Patten and Zhao
	Infrastructure		(2014);
	Quality		Islam and Deegan
	Investment		(2010);
	Benefits	Fairtrade	Global Reporting
	Seasonal products		Initiative (GRI)
	Local dependency	Reducing local dependencies on external market forces	(2013); Carbon Disclosure Project (CDP)
<b>Environmental sustainability</b>	Local sourcing		(2013); International Labour
	Animal welfare		Standards (ILO)
	Green/Efficient energy		(2013); Disclosures on
	Recycle	Reuse	Supply Chain
	Pollution	Chemical/GHG/Air emission	Sustainability
	Packaging	Green packaging	(2011);
	Certificates	Organic/Fairtrade/ Red Tractor, LEAF, Organic,	Mansi (2015);
			Lehtinen (2012); Rimmington et al.

	Marine Stewardship Council or equivalent	(2006); Walker et al. (2012) ;
	Waste	Water/Energy
	Eco-friendly	Biodiversity
	Resource	Water/Land/Solid/Forest
<b>Social sustainability</b>	Community	
	Human rights	Child labor
	Employee health/safety	Wellbeing/Security/Job satisfaction
	Work place	Work condition
	Compensation	Retiring
	Training	Education
	Stakeholder Engagement	
	Customer Privacy	
	Charity	Philanthropic/Donate
	Discrimination	Female/ Race

## RESEARCH METHODOLOGY

This research adopted an in depth critical literature review to develop a framework for measuring sustainability in procurement process. Content analysis was performed on 66 grey and academic literature in order to address the second objective. These included: 5 Annual/Sustainability reports of the case company published between 2011-2016, 23 third party corporation publications, 12 academic research articles focused on co-operatives and 26 newspaper articles. The analysis of literature related to content analysis can be performed efficiently by classifying the collected data into themes or categories. For this purpose, the researcher defined three categories of SP strategies (A), supplier selection criteria (B) SP practices (C) disclosures. Besides the categorisation of data, this study required the adoption of a measurement mechanism for disclosure whereby the contents were identified in relation to 'economic' (10 items), 'environmental' (10 items) and 'social' factors (10 items). The hierarchical structure presented in Figure 2 was adopted and coded. With regard to data interpretation, the researcher assigned binary scores (0 and 1) to the different dimensions of sustainable procurement identified above based on the absence or presence of one element of disclosure (Mansi, 2014). Number of words was used to determine the extent of disclosure. Scores were assigned to the different dimensions of SP identified above based on the number of times the company had disclosed one element (sub-criteria) of disclosure. After that, each frequency number for sub-criteria was divided by the total number of emerged times and then the occurrence rate was obtained, which can be equal to the weights of sub-criteria in the supplier selection process.

## RESULTS AND CONCLUSIONS

### New framework for assessing sustainable procurement performance in retail

The framework for assessing the sustainability of SP performance in coops was constructed from both a horizontal and a longitudinal perspective (Fig 1). From the horizontal perspective, SP performance of Coop Food was compared from economic, environmental and social dimensions and the archetype of sustainable sourcing profiles were identified in Figure 2. In terms of the longitudinal dimension, SP performance in each activity, such as SP strategies, supplier selection and SP practices were analysed. The top ten principles and criteria as identified in the literature were selected to examine the gap between the strategies and practices.

### Sustainable procurement performance assessment in the case company

SP performance at case company was assessed from three perspectives, SP strategies, SP practices and sustainable supplier selection criteria. The maximum disclosures were

observed for social sustainability (45%) and environmental sustainability (43%) criteria compared to economic sustainability (12%). Regarding environmental criteria, the top three requirements in supplier selection criteria were 'activities in reducing pollution', 'products with environmental certificates' and 'the implementation of an environmental management system'. However, 'recycling' featured less heavily, which is interesting

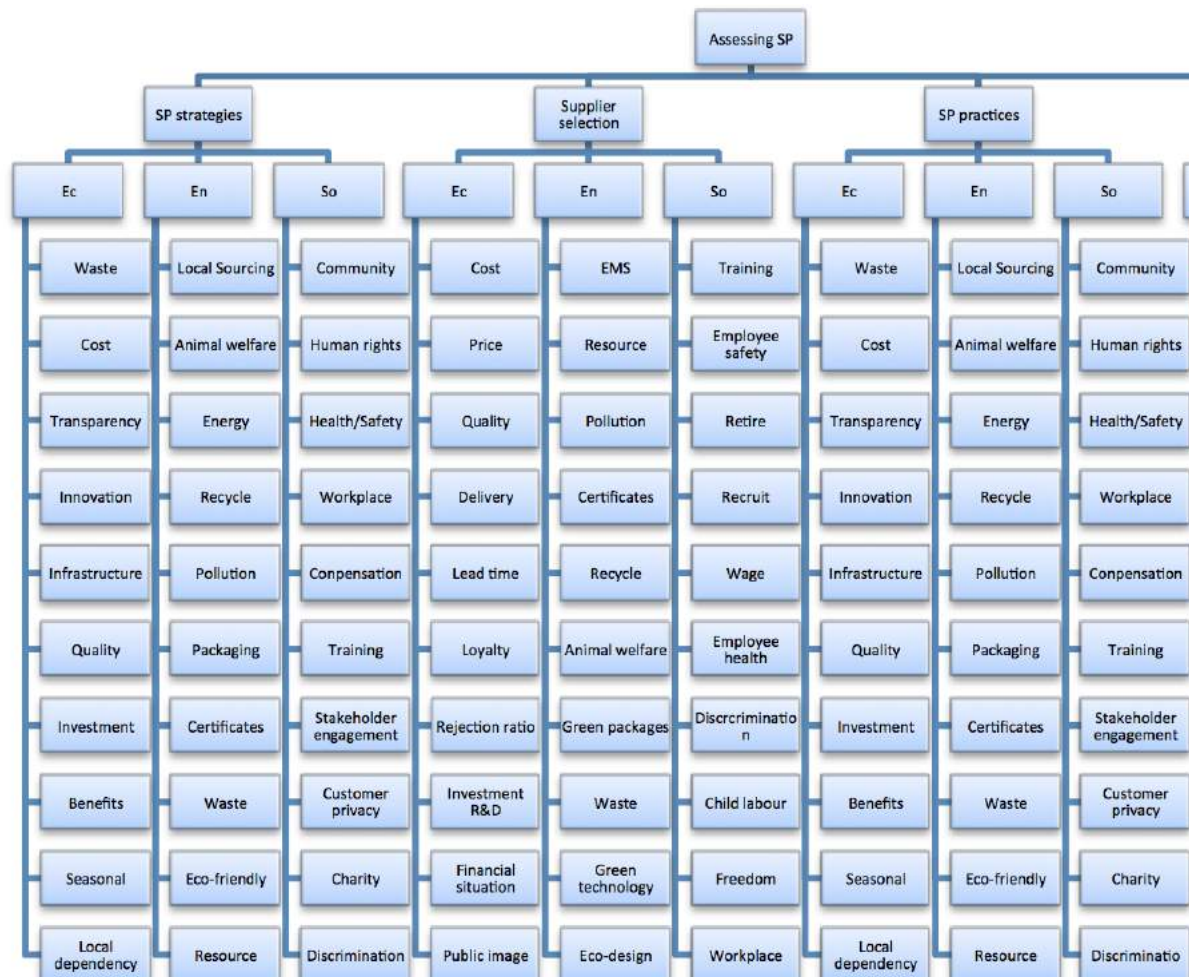


Figure2. The new framework for assessing the sustainable procurement performance

considering the Global Reporting Initiative and the United Nations Environmental Programme advise the incorporation of recycling programmes into environmental initiatives (GRI, 2013). Nonetheless, the case company stated that they will provide recycling facilities for suppliers to increase the recyclability of packaging so they did not require suppliers to implement their own recycling policies and facilities. With regard to the social dimension, 'child labour', 'worker training' and 'employee safety and health' were more prominent than other social criteria such as 'wage', 'creating job opportunities' and 'discrimination' are also highly ranked. It is also clear that there is no common trend for the ranking of social criteria in prior literature (e.g. Nielsen et al., 2014; Ahi and Searcy, 2015). This may be attributable to the fact that the social dimension is a new area in the SP field and the results may be better rationalised by a broader sample of literature or an alternative research focus. Based on the comparison of results of this study to those in the literature, as expected, social issues including 'the percentage of retiring' and 'forced labour' are not highly ranked as social criteria as intimated by the IOL along with other institutions. For the economic dimension, while other studies highlighted the price/cost as one the main criteria for supplier selection in retail sector (Humphreys et al. 2003 and Cheraghi et al. 2004), this research showed that loyalty, quality and on-time delivery were the top three economic sustainability

criteria for co-operatives. Comparison of SP strategies and practices revealed that the case company underperformed in the area of quality control, sourcing seasonal food and philanthropy and this needs further investigation through primary data analysis.

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# TRANSPORT OPERATIONS IN REUSABLE PACKAGE SUPPLY CHAINS: THE ROLE OF INTERMODALITY IN REDUCING THE ENVIRONMENTAL IMPACT

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## **Abstract**

### **Purpose of this paper:**

This paper aims to quantify the logistics and environmental impacts reduction associated to the use of intermodality for the delivery, collection, and transport processes of a closed-loop supply chain of reusable plastic crates for fruit and vegetable products.

### **Design/methodology/approach:**

The adopted approach focus on the optimization of the transport process, minimizing the level of approximation in the input data. To validate the proposed approach a multi-scenario what-if analysis is performed according to the case study from the network of an Italian pooler operating in the retail supply chain on fruit and vegetable. Results are generated through a decision support tool that aids a data-driven assessment of the storage and distribution operations experienced by the reusable plastic crates. This tool imports the business case data instance, embeds a Geographic Information System (GIS), and implements an accounting functionality that quantifies the travelling distance, the environmental impacts (e.g., GHGs emissions) and the costs associated to the transport activities.

### **Findings:**

We quantify the main categories of impacts among the set of accounted greenhouse gases emissions and the total transportation costs. Results showcase a total transportation costs reduction of the 11,7% in the proposed to-be scenario, while the number of kilograms of CO<sub>2</sub>Eq decreases by the 9,2%.

### **Value:**

The original contribution of this paper lies on the research area of the investigation of closed loop supply chains (CLSC) performance in relationships with the sustainability topic. Moreover, differently from other approach to the evaluation of the environmental impacts (e.g. the LCA), this paper reduce the boundaries of the analysis to the transport process only, however focusing on the minimization of the level of data approximation while enhancing the reliability of the results.

### **Practical implications:**

We illustrate an approach and a support-decision tool that allow the analysis and quantification of the costs, impacts and benefits resulting by the adoption of alternative modes of transport in a reusable packaging system. Therefore, practical implications involve helping managers of re-usable package pooling systems in the decision-making about the adoption of intermodality. Furthermore, the simulation tool may support fruit and vegetables producers in the decision-making process over the type of package network to implement.

**Keywords:** Returnable packaging, Reverse chain, Transport, Intermodality

## 1. INTRODUCTION

Packaging plays a crucial role in the food industry, which is the first in the European Communities for revenues (FOODDRINK Europe, 2016). The processing of virgin materials, such as plastic and glass, to produce package highly contributes to enhance the industrial sector's demand for energy. For this reason, in recent years the reusable food packaging networks have caught the eye of both scholars and practitioners not only to save energy but also to prevent waste production (Tonn et al., 2014). According to the report from Stiftung Initiative Mehrweg, the market share associated with the usage of re-usable packaging for the transportation of fruit and vegetables is estimated to be around 40% in Europe (Mehrweg, 2007). The implementation of re-usable packaging network supports the creation of the so-called closed-loop systems aided to create value over the entire life-cycle of products (Daniel et al., 2009). However, the required reverse transport flows as well as the package washing process enhance the logistics complexity if compared with the traditional one-way packaging systems (Wu and Dunn, 1995). Moreover, package travels along wider network producing higher transportation costs and greater environmental impact (Accorsi et al., 2014).

Therefore, a careful transportation planning is crucial in reducing the costs associated to both forward and reverse logistics in those closed-loop supply chains (CLSC). Particularly, Albrecht et al. point out how the longer the transport distance the more significant the impact of the cost generated by the backhaul trips for the re-usable systems is. Therefore, while single-use packaging is preferred in fruit and vegetables transportation characterized by long distances, re-usable package results economically and environmentally sustainable with shorter distances (Albrecht et al., 2013). However, the geographical location of the nodes in the network is not the only factor to consider in deciding whether to use reusable package. Shipments consolidation, route planning optimization and the choice of more sustainable modes of transport may contribute to decrease the total impact associated with the transport process, supporting the management of the logistics complexity and increasing the convenience of using re-usable package solutions.

Particularly, the paper focus on the adoption of intermodality in reusable package CLCS. This work was primarily motivated by the lack in the literature of integrated studies that tie together the sustainability goal and the management of CLCS. Moreover, the following investigation is based on the idea that: whether the environmental impact of the transport, storage and washing processes overcomes the benefits generated by the reduction of the impact of production (i.e. due to the re-use of the package), the convenience of re-usable package ended.

For this reason, managers should deeper focus on the optimization of the transport process. This would necessitate achieving a full understanding of the analysed system, in order to identify potential scopes for improvement and implement effective solutions. Consequently, a significant phase of this study is devoted to the data collection to reduce the level of uncertainty related to the presence of lacking and ambiguous data. Differently from one of the most common approach to the evaluation of the environmental impacts, the Life Cycle Assessment (LCA analysis)(ISO 14040 2006), this paper reduce the boundaries of the analysis to the transport process only, however minimizing the level of data approximation. Differently, several researchers point out how uncertainties, such as subjective judgment, statistical variation and, errors, are quite common in LCA studies, reducing the reliability of the results (Heijungs and Huijbregts, 2004).

To validate the effect of the proposed approach an innovative tool for the analysis of the costs and impacts associated to a given distribution and transport network is used. The tool supports the implementation of a what-is multi-scenario analysis campaign to compare the effects of different intermodality solutions, quantifying the main categories of impacts among the set of accounted greenhouse gases emissions as well as the total travelled distance.

Therefore, aim of this paper is helping managers of re-usable package pooling systems in the decision-making about the adoption of intermodality. A case study from an Italian pooler operating in the retail supply chain on fruit and vegetable is presented.

The remainder of this paper is organized as follows. Section 2 provides a literature review, while Section 3 illustrates the methodology. Section 4 reports the results from the case study,

which are further discussed in section 5. Finally, Section 6 concludes the paper, reassuming the main contents.

## 2. LITERATURE REVIEW

The state-of-the-art concerning the re-usable package pooling systems with life-cycle considerations is limited to few recent works. In 2015, Govindan et al. present a survey about reverse logistics and CLSC, where they underline a gap in the literature about the investigation of those topics in relationships with sustainability and green supply chains. Several of the existing studies are aided to compare the performance of re-usable and single-use package in order to find the most environmentally friendly solution (Levi et al., 2011). Such contributions reveals how material is not the only factor to consider, but the entire supply chain should be analysed in the comprehensive perspective. The transport process, which sometimes is touted as a reason to not implement reusable package systems (Pearce, 1997), greatly contributes to enhance the environmental impact, resulting more critical in re-usable package pooling systems such as RPC systems (Levi et al., 2011). According to Koskela et al. (2014) the distance, the modes of transport and the load are the most important factors concerning transport impact. Wide distribution area may require long backhaul trips, discouraging the use of re-usable package (Albrecht et al., 2013). Although, the great value of coordination between forward and reverse flows on CLSC performance (i.e. in terms of inventory and logistics costs optimization, and service levels enhancement) is recognize by Elia and Gnani (2015). Therefore, a major coordination may lead to the design of pooling network over a strategic perspective (Accorsi et al., 2015). As instance, (Ross and Evans, 2003) underline how environmental impact can be reduced by changing the geographical location of some CLSC processes. Moreover, coordination may support the consolidation of shipments in supply chain and the transport planning, reducing the greenhouse gas emissions (Pan et al., 2013). Lastly, the value of intermodality on the environmental impact reduction is well-established in the literature (Bontekoning et al., 2008). Particularly, (Chapman, 2007) provides a comprehensive survey, where the contributions of the different modes of transports on the climate change are discussed.

## 3. METHODOLOGY

This paper evaluates the impact on logistics and environmental metrics resulting by the redesign of a reusable package network. More precisely, we consider transport modality alternative choices to support the reduction of environmental impacts. The adopted methodology involves the analysis of a case study from the network of an Italian pooler operating in the retail supply chain on fruit and vegetable. The company provides fruit and vegetables growers with reusable plastic crates (RPC) of different dimensions, creating a wide system that not only involve the facilities owned by the pooler but also raw material suppliers, retailers and plastics recycling centers.

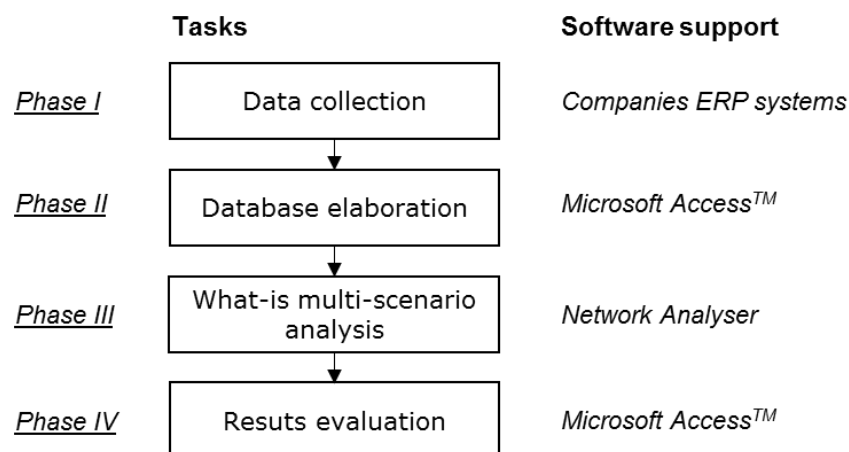


Figure 1- Overview of the methodology utilized in the case study



Figure 1 illustrates the methodology applied to the case study. An initial phase of data collection (Phase I) allows to gather information on the transportation process of raw materials, semfinished and finished products over the whole network during a time horizon (i.e. one year). Data is mainly extracted from ERP systems of the companies involved in the network.

In Phase III, a what-if multi-scenario analysis is performed in order to compare the environmental costs generated by the current transportation system (*as-is*) with a simulated scenario (*to-be*) over the selected time horizon. In the *to-be* scenario, transportation flows are re-arranged in order to make a greater use of intermodality.

Results are generated through a simulation tool written in C#.Net, Network Analyzer, which imports data from a structured database and embeds the connection with a geographic information system (GIS). Then, it quantifies environmental KPIs resulting by the analysed scenario. For this reason, the collected data should be previously arranged in order to fit with the database structure (Phase II). Tables include information on products (e.g. products code, products description, sizes), shipments (e.g. order code, order quantity), nodes (e.g. node name, address) and modes of transport (e.g. railway, seaway). At first, the simulation tool opens the connection with the database and import the geographical coordinates of the nodes. Then, it calculates the road distances in kilometers among the nodes, building a *from-to* chart. The next step involves the flow quantification over the simulated time horizon in term of kilometers per shipment. A set of user-friendly graphic user interfaces (GUIs) allow the visualization of the flows on the map, as shown in Figure 2. For reasons of readability, flows are shown through Euclidean distances.

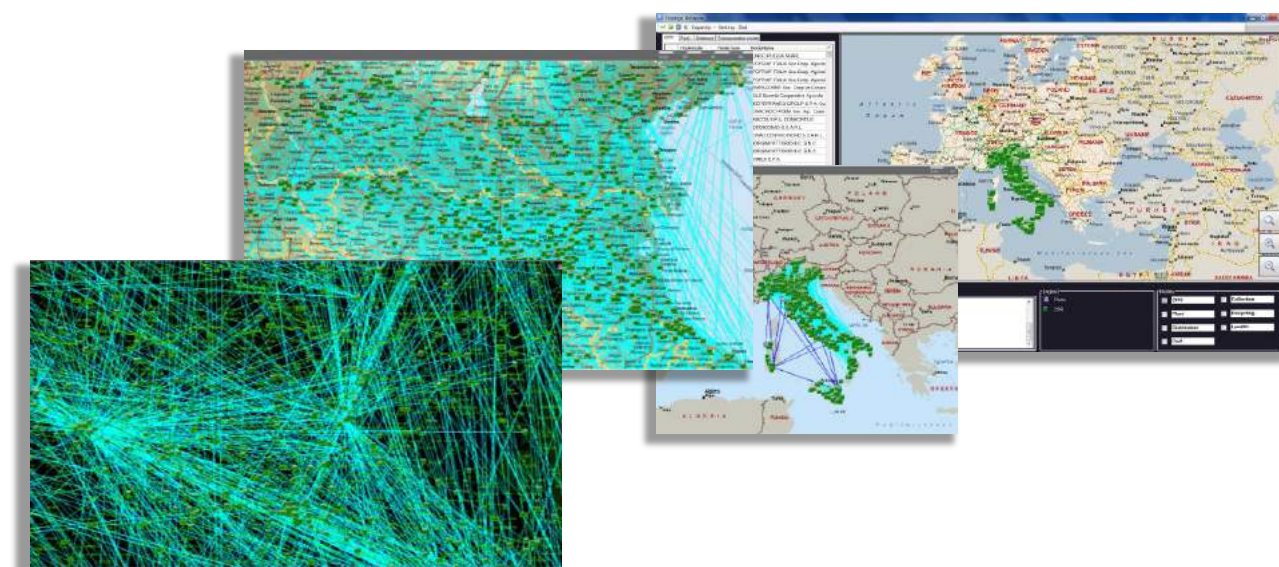


Figure 2- GUIs from Network Analyser

As last step, the tool provides statistics on the main GHG gas emissions, enabling the user to compare the effects of different logistics choices during Phase IV. As instance, the tool is able to calculate the emissions produced by scenarios characterized by different modes of transport and different level of means saturation (i.e. if full or partially loaded), according to the Finnish Lipasto Database (VTT Technical Research Centre of Finland 2015).

Furthermore, the database allows to quantify the dimensional weight for each shipment. Then, transportation costs are calculated according to the report of Confcommercio (2015), which monitored the average transportation cost (Tons·Euro·Km) in Italy over a time horizon of 6 years (from 2007 to 2013) for the different modes of transport.

## CASE STUDY

The analysed pooling network involves more than 1500 nodes located all over the Italian country. Figure 3 summarizes the different type of players and the relationships among them in terms of materials flows.



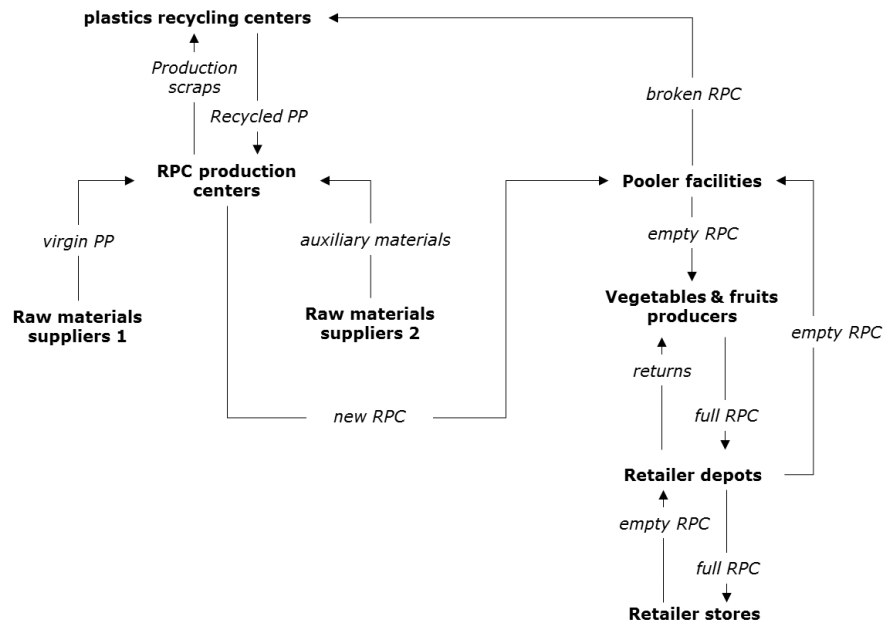


Figure 3-Pooling network overview

The pooler facilities provide 1068 vegetables and fruit producers with empty crates, which are filled and sent to the retailers depots. These supply the retailers store with the full RPCs and collect the dirty ones and the returns. Note that the RPCs present the advantage of reducing the space occupation of the 70% (when closed), enhancing the number of shipped crates per trucks. Successively, the retailer depots return the dirty creates to the pooler facilities to be subjected to washing process. Due to logistics complexity, currently the pooling company washes the 50% of the dirty crates over a year but, several efforts are directed to enhance the percentage to 100%. Crates present an average service life of 10 years. However, at the end of their life, they are not disposed but recovered to produce recycled PP. A similar process involves the management of the broken crates. The new RPCs are produced by the RPC production centers, which combine the recycled PP with virgin PP and auxiliary materials generating a completely closed-loop system.

At the current state (*as-is*) transportation is entrusted to 3PL suppliers that deals with the problem of balancing the crates' flows in a country in which vegetables and fruit producers are concentrated in the south. Therefore, the geographical dispersion and elevated number of network players influence the transportation management. Moreover, it is a best practice for 3PLs to consolidate RPCs with other type of products in order to saturate trucks and exploit economies of scales. Although trucks results more saturated, RPCs may travel for longer distance to address to the needs of the other 3PLs customers. The boundaries of this analysis include only the actors involved in the pooling network, considering the goods transported for the other 3PL customers as negligible. For this reason, in some shipments simulation results may suffer from a less means saturation if compared with the reality, returning higher emissions. Table 1 reports the main simulation parameters referred to the analyzed time horizon (1/01/2015 – 12/31/2015).

Simulation parameters (01/01/2015 - 12/31/2015)			
<u>Nodes</u>	<u>N°</u>	<u>Modes of transports</u>	<u>Tons</u>
Plastics recycling centers	1	Tipper lorry	25
RPC production centers	2	Tanker	25
Raw materials suppliers	10		
Pooler facilities	34	<u>Shipments</u>	<u>N°</u>
Vegetables & fruits producers	1068		
Retailer depots and stores	487	Number of shipments	671173
		Handled goods [Tons]	965308

Scenario as-is	Scenario to-be
----------------	----------------

Table 1- Simulation parameters

Two simulated scenarios reproduce the collection and distribution flows of 965,308 tons of goods (i.e. empty and full pallets, raw materials, broken crates) across the network. Due to the lack of information on the exact trucks capacity utilized by the 3PLs in each shipments, a single type of tipper lorry with a maximum capacity of 25 tons is considered. Similarly, goods transported through the seaway are stocked on a tankers of 25 tons of capacity. Due to the introduced assumptions are valid for both scenarios, the simulation results can be considered as comparable and representative.

In the *as-is* scenario, the major part of the shipments to and from Sicily, which together account for the 8.7%, pass through the port of Naples even though the departure/destination nodes are located in the north of Italy. In some extreme cases, crates travels on trucks until the Strait of Messina. Diversely, the proposed to be scenario suggests reducing the number of travelled road distance by favoring the seaway. Although shipping is mainly implied for overseas freight while road transport represent a more viable option for a small country like Italy, it is considered as a more sustainable mode of transport (Schipper & Fulton 2003) . As shown in table 1, three new sea routes connect Sicily with the port of Genoa, the port of Leghorn and, the port of Rome. Compared with the *as-is* scenario, the simulation reveal a reduction of the total travelled distance of around 811,000 km, while the number of kilometers travelled by the tankers increases of the 90.7%. According to (Confcommercio, 2015), shipping reveals the lowest cost for transported ton if compares with the other means of transport. Thus generates a total transportation cost reduction of the 11,7%, as reported in figure 4.

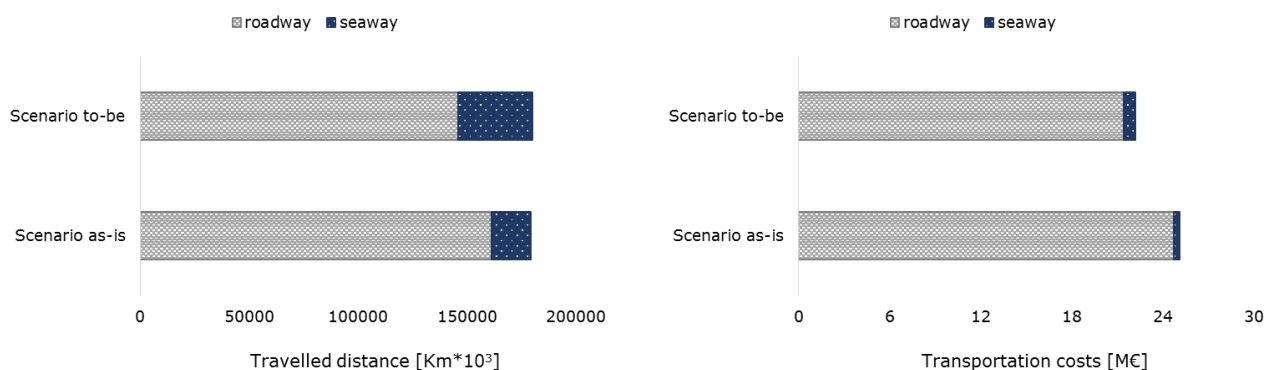


Figure 4- Simulation results

The obtaining environmental GHG emissions are reported in Table 2. The to-be scenario the value of all categories of GHG emission decreases. As expected, the only exception is represented by sulphur particles, which are emitted in large volumes by ships (Chapman 2007). Generally, the to-be scenario generates a reduction of the kilograms of Co2Eq, which represents the total global warming potential, of the 9.2% showcasing the importance of exploiting intermodality in order to achieve a higher level of sustainability.

<b>GHG Emission</b>	<b>scenario as-is [Kg]</b>	<b>scenario to-be [Kg]</b>	<b>difference from as-is</b>
CO	26,324.6	24,243.4	-7.9%
HC	14,926.5	13,573.4	-9.1%
NOx	952,738.8	873,325.8	-8.3%
PM	8408.7	7,891.3	-6.2%
CH4	1,171.0	1,103.6	-5.8%
N2O	4,564.4	4,139.9	-9.3%
NH3	806.1	728.8	-9.6%
SO2	5042.1	9,035.7	79.2%
CO2	123,537,369.7	112,180,200.4	-9.2%
Co2Eq	124,995,568.7	113,498,245.0	-9.20%

Table 2- GHG Emissions: as-is vs. to-be scenario

#### 4. DISCUSSION

Despite of the need of further analysis to validate the proposed approach and the tool with other case studies, results arise some considerations. First, the results showcase how the to-be scenario achieves the twofold objective of reducing the total transportation cost while decreasing the environmental impact. Further analysis may involve the evaluation of the railway option, which is currently under development from the pooler company.

The data gathering process represents the most time-intensive activity. The proposed approach requires a high level of input data accuracy in order to elaborate reliable results. Thus allows to compare the potential benefits of an alternative scenario according to the lowest level of approximation. Therefore, to replicate the study in another context, an elevated company commitment is required in order to involve the elevated number of network players in the data collection process.

This paper represents the first step of a more ambitious project in which the final aim deals with providing managers with a reliable user-friendly simulation tool tailored for closed loop systems. Furthermore, the simulation tool may support fruit and vegetables producers in the decision-making process over the type of package network, quantifying the potential incremental advantages of adopting a re-usable system. While the current version of the tool is able to quantify the effect of a given scenario, further functions could automatically design alternative improvement scenarios starting from the data analysis.

#### 5. CONCLUSION

This paper is among a few in the literature that link the topic of sustainability and the performance of CLCS. Through a year-long case study, the paper assess the environmental impact reduction generated by a greater use of intermodality in reusable packaging network. The case study is provided by an Italian RPC pooler, operating in a network of more than 1600 nodes around Italy. Results showcase a total transportation costs reduction of the 11.7% in the to-be scenario, while the kilograms of CO2Eq decrease by the 9.2%. The originality of this paper lies in the adoption of an approach aided to focus on the optimization of the transport process, minimizing the level of approximation in the input data and in the results. Despite

the need for further analysis, the authors believe that this paper represents a valuable proof of concept.

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## **ENVIRONMENTALLY RESPONSIBLE MANAGERS - A EUROPEAN COMPARATIVE STUDY**

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## **Abstract**

### **Purpose of this paper:**

The main purpose of this paper is to identify the role of environmentally responsible managers in sustainable supply chain management. Modern managers are responsible not only for the final results of business activities but also for implementation and understanding of environmental issues in companies. It means they need to have specific skills and knowledge related to the issue of sustainability. The proposed paper will analyse skills needed for green management. Along with theoretical study it will present the research results of the international TrainERGY project (<http://www.trainergy-project.eu/>) aimed at promoting green thinking among enterprises and academics across Europe.

### **Design/methodology/approach:**

A two-phase methodology design based on the secondary sources review and a survey was used. Desk research method contributed to the theoretical background of the article,

whereas the survey research provides the data on environmental skills related to 132 SMEs operating in four European countries: Poland, United Kingdom, Italy and Greece. The analysed skill areas are as follows: use of technologies that support EEO (Energy Efficient Operations) initiatives, green strategic planning, decision making in green supply chain management, environmental audit and policies guidelines, measuring and monitoring environmental performances.

**Findings:**

The findings of the research cover the differences between countries in terms of managers' environmental skills presence index which is a measure representing presence of particular skills in the surveyed companies)

**Value:**

The paper presents the unique research results on the managerial skills needs which development should be primarily taken into account by both top management and academics.

**Research limitations/implications (if applicable):**

The presented analysis includes a preliminary sample of the companies operating in researched countries.

**Practical implications (if applicable):**

The article brings the information on the environmental skills needed to manage companies in more environmentally responsible way. It also highlights the essential directions of a design and a content of the current and future environmental education and practice.

**INTRODUCTION**

The concept of sustainable development understood as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987) is still broadly discussed despite its long tradition. The concept is strictly related to the problem of satisfying needs of different stakeholders in changing socio-economic circumstances. Moreover the concept from macro level approach was transferred to different sub concepts which evolved as new ideas like sustainable supply chain management which is it the point of interest of this paper. The concept of sustainable supply chain management is well identified in literature (Seuring and Müller, 2008a, 2008b; Carter and Rogers, 2008; Linton et al., 2007, Hassini et. al, 2012). The issue of sustainability in supply chain is used to manage social and environmental aspects directly related to the business processes. It means that some specific competences and knowledge of managers are required to understand and correctly implement noneconomic goals into the company and its supply chains. There are many different research and theoretical papers oriented on the problem of education for sustainability covering different aspects like conceptualization of competences, key competences needed, methods of acquiring competences etc. (Byrne 2000; Barth et al. 2007; Sipos et al. 2008; Willard et al. 2010, Steiner and Posch 2006). Different kinds of competences can be identified like e.g.: system-thinking, normative, strategic, anticipatory and interpersonal competences (Wiek et. al 2011). Following the set of competences required, equally important aspect appears to be the integration of sustainability in management education (Raufflet 2013) and in universities (Nicolaidis 2006). The issue of competences for sustainability is crucial, due to fact, the acquired competences will be reflected in the way decision makers tackle with business processes.

Education for sustainability continues to be a challenge not only in formal education but also in long-life learning approach. A success of sustainability oriented projects depends on the personal engagement of managers and their awareness of environmental challenges developed during educational process. Therefore, it would seem reasonable to examine not only the general competences but also specific areas of knowledge and skills crucial for developing sustainability practices.

The main purpose of the paper is to analyse the issue of different skills needed for developing green / sustainable practices in supply chains. The attention will be put on different areas related to sustainability required for appropriate management abilities, grouped in categories like: technologies, databases and specific software tools for reducing processes' environmental impact, strategic orientation on green issues or green internal and external management operations. Two different indexes were proposed to analyse the presence and level of possessing different skills / competences supporting sustainability on managerial level. The study will present comparative research results of the international project: Training for Energy Efficient Operations (Trainergy) (<http://www.trainergy-project.eu>) aimed at promoting green thinking among enterprises and academics across Europe.

## **METHODOLOGY**

The research was conducted in four European countries: Poland, United Kingdom, Italy and Greece. The aim of the research was to identify the presence of the energy efficient operations (EEO) competences at each specific location. The questionnaire was prepared following the enumerated steps:

1. Skill areas definition: i.e. definition of priorities areas in which SMEs need to improve their energy efficient operations skills. The skill areas was defined basing on the results of an international project PrESS - Promoting Environmentally Sustainable SMEs undertaken by the same consortium as for the Trainergy project.
2. Analysis of existing EEO curricula identified within the countries the project is implemented and beyond (Italy, UK, Poland, Greece, Spain, France, and Germany) and databases specialized in the higher education web marketing<sup>1</sup>.
3. Main topics identification: i.e. analysis of the topics included in the courses of the curricula identified in step 2.
4. Main topics classification: allocation of the main topics identified to the skill areas defined in step 1.
5. Skills definitions: defining the specific requirements for each skill within the identified areas and adapting them for the research questionnaire.

For the purpose of the research 64 programmes have been analysed in the countries covered by the project and beyond, which resulted in 282 main topics identification, that further have been allocated into 18 specific competences areas. Additionally, the specific competences areas belonging to the same category have been grouped in 5 categories as shown in table 1.

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<sup>1</sup> Master studies, <https://www.masterstudies.com/>, accessed 10.11.2016

<b>Category</b>	<b>Specific competences areas</b>
Technologies, databases and specific software tools for reducing processes' environmental impact	1. Technologies for reducing energy consumption 2. Technologies for reducing pollution 3. Technologies for reducing consumption of raw materials 4. Technologies for reducing waste 5. Tools and Decision Support Systems for supporting environmental decisions 6. Database management systems for supporting environmental decision
Strategic orientation in terms of Green Innovation, Purchasing, Marketing	7. Green Innovation 8. Green Purchasing 9. Green Marketing
Green internal and external operation management	10. Green internal operations management 11. Green external operations management
Environmental principles, regulations, certifications and activities reporting	12. Environmental regulatory frameworks 13. Environmental certifications 14. Audit principles 15. Reporting activities
Definition of objectives and performance indicators, Checking and Interventions Planning	16. Definition of environmental objectives and environmental performance indicators (EPIs) 17. Measuring Environmental Performance Indicators (EPIs) 18. Interventions identification

Table 1: Competences required for implementing energy efficient and sustainable operations

The research focused on testing the theoretical and practical EEO skills coverage within companies. The questionnaire involved two questions per each skill, investigating the following dimensions (defined according to the Dublin Descriptors):

- Knowledge and understanding;
- Applying knowledge and understanding.

For all surveyed EEO skills a 5 point Likert scale was used, ranging from 1 (minimum) to 5 (maximum).

The survey was conducted from October to December 2016. A total number of 134 valid responses was obtained with the following distribution among the participating countries: Poland - 56 questionnaires, United Kingdom - 25 questionnaires, Italy - 28 questionnaires and Greece - 25 questionnaires. The survey can be further characterized by:

- Business sectors, including: manufacturing (26.1%), construction (23.1%), retail/commerce (11.9%), food and winery (10.4%), transportation/logistics (9.0%), healthcare services (6.7%) and other (12.7%).
- Number of employees, including: under 25 (41.0%), 26 to 50 (22.4%), 51 to 250 (26.1%) and more than 250 (10.4%).

On the basis of the survey results a skill matrix for each country was developed. The skill matrix development methodology involved the calculation of the two following indexes: covering index (CI) and presence index PI, explained in table 2.



<b>Index name</b>	<b>Index definition</b>
Covering index (CI <sub>ik</sub> )	$CI_{ik} = \frac{n_{ik}}{N_i}$ <p><math>n_{ik}</math> - number of courses provided by country <math>i</math> covering the skill <math>k</math>;  <math>N_i</math> - total number of courses provided by country <math>i</math>;</p>
Presence index (PI <sub>k</sub> )	$PI_k = \sum_{j=1}^5 (RR_{jk} * w_j)$ <p><math>w_j</math> - weight associated to the response <math>j</math>, <math>\forall j = 1,2,3,4,5</math>  <math>RR_{jk}</math> - rate of response <math>j</math> recorded per skill <math>k</math></p>

Table 2: Covering index and presence index definitions

Considering these two dimensions, the EEO skills can be presented in a graph with the PI on the x-axis and CI on the y-axis. The four main quadrants can be identified in the graph, as shown in Figure 1.

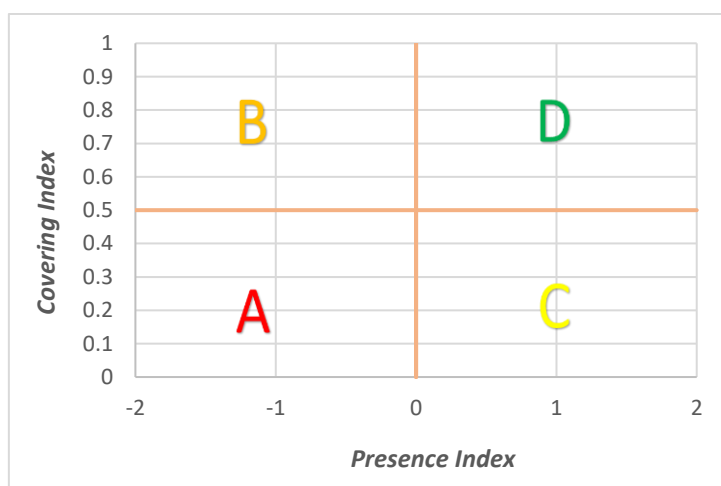


Figure 1: Skill Matrix

Particular skills are the points in this graph and according to the position occupied on it, they will be classified as belonging to one of the following categories:

- A - Slightly covered or not covered skills, but not possessed/used at all;
- B - Covered skills, but not possessed/used at all;
- C - Slightly covered or not covered skills, but possessed/used at all;
- D - Covered skills, possessed/used at all.

This approach allowed to prepare an individual skill matrix for each country what is presented in the next section of the paper.

## RESEARCH RESULTS AND FINDINGS

The results of the CI and PI calculations, as well as class categorisation according to the developed skill matrix methodology is presented in the table below.

<b>Skills</b>	<b>Poland</b>			<b>Italy</b>			<b>Greece</b>			<b>United Kingdom</b>		
	<b>CI</b>	<b>PI</b>	<b>Class</b>	<b>CI</b>	<b>PI</b>	<b>Class</b>	<b>CI</b>	<b>PI</b>	<b>Class</b>	<b>CI</b>	<b>PI</b>	<b>Class</b>
Technologies for energy consumption (reducing consumption)	0.50	-0.32	B	0.58	-0.04	B	0.20	0.42	C	0.50	0.54	D
Technologies for energy consumption (renewable sources)	0.50	-0.86	B	0.58	-0.11	B	0.20	0.46	C	0.50	0.39	D
Technologies for reducing pollution	0.30	-0.39	A	0.00	-0.14	A	0.00	0.44	C	0.29	0.70	C
Technologies for reducing consumption raw materials	0.60	-0.31	B	0.08	-0.30	A	0.00	0.50	C	0.21	0.57	C
Technologies for reducing waste	0.40	0.02	A	0.08	0.48	C	0.20	0.64	C	0.07	0.86	C
Tools and DSS for supporting environmental decisions	0.50	-0.89	B	0.17	-0.71	A	0.80	0.16	D	0.14	0.78	C
Database management systems	0.60	-1.35	B	0.17	-0.95	A	0.20	0.00	C	0.00	1.09	C
Green innovation (new product/services development. eco-design)	0.60	-0.87	B	0.67	-0.48	B	0.40	0.32	C	0.64	0.80	D
Green purchasing	0.00	0.07	A	0.00	0.15	A	0.00	0.99	C	0.00	0.93	C
Green marketing	0.00	-0.70	A	0.25	-0.45	A	0.00	0.34	C	0.07	0.70	C
Green internal operations management	0.10	-0.56	A	0.50	-0.36	B	0.40	0.44	C	0.21	0.98	C
Green external operations management	0.10	-0.57	A	0.25	-0.08	A	0.40	0.91	C	0.07	1.13	C
Environmental regulatory frameworks	0.60	-0.62	B	0.75	-0.20	B	0.80	0.42	D	0.57	1.02	D
Environmental certifications	0.20	-0.82	A	0.17	-0.16	A	0.20	0.38	C	0.00	1.33	C
Auditing activities	0.10	-0.91	A	0.17	-0.61	A	0.20	0.44	C	0.21	1.09	C
Reporting activities	0.20	-0.92	A	0.08	-0.75	A	0.00	0.36	C	0.07	0.87	C
Definition of Environmental objectives and Environmental Performance Indicators (EPIs)	0.60	-0.96	B	0.08	-0.61	A	0.40	0.32	C	0.29	0.89	C
Measuring EPIs	0.60	-1.05	B	0.17	-0.79	A	0.40	0.36	C	0.21	0.76	C

Table 3: Covering index (CI), presence index (PI) and class according to the skill matrix for Poland, Italy, Greece and United Kingdom

For better visualisation, the results are also presented on a chart (Figure 2).

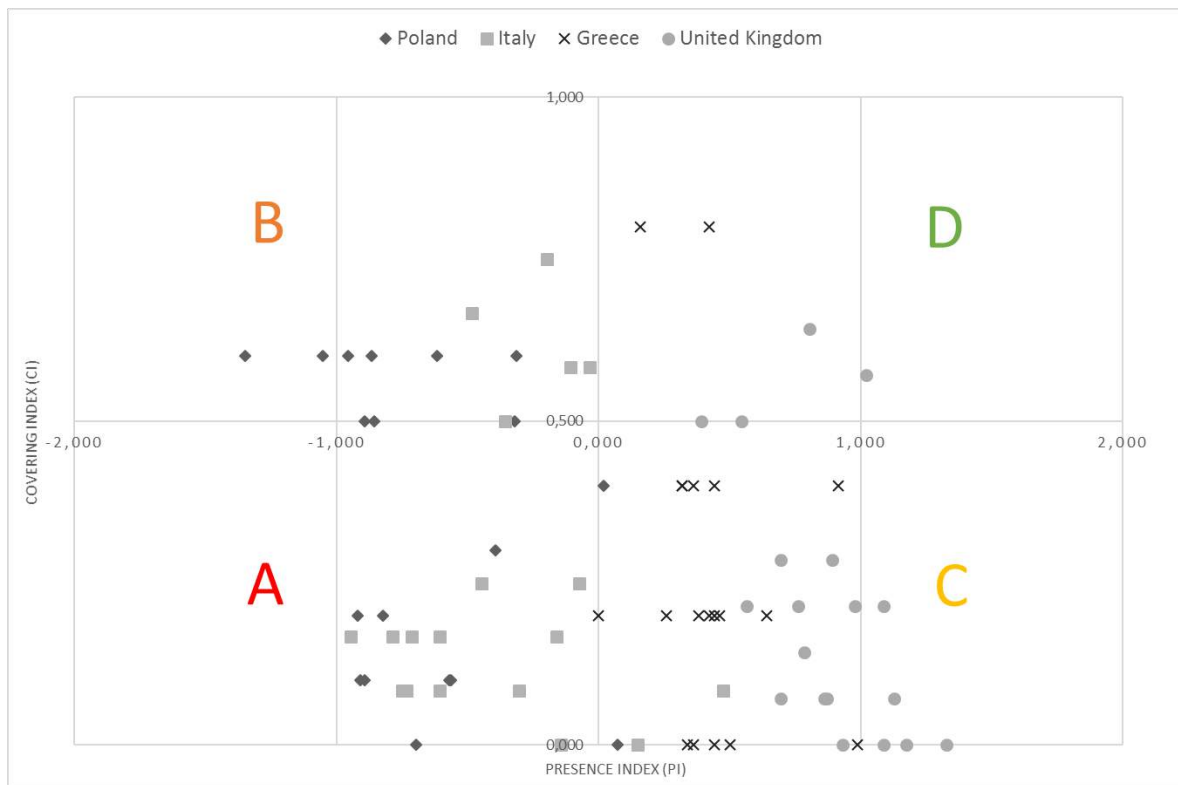


Figure 2: Covering index (CI), presence index (PI) and class according to the skill matrix for Poland, Italy, Greece and United Kingdom

The differences in distribution of the CI and the PI were analysed using Kruskal-Wallis one-way ANOVA on ranks (Spurrier 2003). According to the calculations there were no significant differences in the covering index between the analysed countries ( $H=3.446916$ ;  $p=0.3277$ ) and there were significant differences in the presence index ( $H=60.43321$ ;  $p=0.0000$ ). The detailed analysis revealed that there were no differences in distribution of the presence index between Poland and Italy ( $p=1.000000$ ), as well as Greece and United Kingdom ( $p=0.136632$ ), which means that Polish and Italians companies as well as Greek and British are on similar level in terms of the advancement of the analysed skills implementation. All other comparisons disclosed significant differences between the analysed countries (Poland vs Greece:  $p=0.000014$ ; Poland vs United Kingdom:  $p=0.000000$ , Italy vs Greece:  $p=0.005117$ , Italy vs United Kingdom:  $p=0.000000$ ). The analysis of research results exposed that skills requiring the strongest intervention (those with the lowest values of the covering index and the presence index) overlap between the countries, as shown in table 4.

<b>Country</b>	<b>Priority skills</b>
Poland	<ol style="list-style-type: none"> <li>1. Green marketing</li> <li>2. Auditing activities</li> <li>3. Interventions identification</li> <li>4. Green purchasing</li> <li>5. Green external operations management</li> </ol>
Italy	<ol style="list-style-type: none"> <li>6. Green purchasing</li> <li>7. Reporting activities</li> <li>8. Interventions identification</li> <li>9. Database management systems</li> <li>10. Definition of Environmental objectives and Environmental Performance Indicators (EPIs)</li> </ol>
Greece	<ol style="list-style-type: none"> <li>11. Green marketing</li> <li>12. Reporting activities</li> <li>13. Technologies for reducing pollution</li> <li>14. Technologies for reducing consumption raw materials</li> <li>15. Green purchasing</li> </ol>
United Kingdom	<ol style="list-style-type: none"> <li>16. Green purchasing</li> <li>17. Technologies for reducing waste</li> <li>18. Green marketing</li> <li>19. Database management systems</li> <li>20. Green external operations management</li> </ol>

Table 4: Priority skills for Poland, Italy, Greece and United Kingdom

"Green purchasing" was identified as top priority skill in Italy and United Kingdom, whereas "green marketing" was the top priority skill in Poland and Greece. Low coverage in terms of skills' presence in educational programmes and company's experiences could also be observed with relation to "auditing activities" (rank 2 in Poland), "reporting activities" (rank 2 in Italy and Greece) and "interventions identification" (rank 3 in Poland and Italy). Among other skills requiring the strongest intervention were also those connected with operations management (green external operations management) and various types of technologies used for improving the sustainability of operations (technologies for reducing pollution, technologies for reducing consumption raw materials and technologies for reducing waste).

## SUMMARY

The paper presents a comparative research results on the managerial skills needs which development should be primarily taken into account by both top management and academics. The article brings the information on the environmental skills needed to manage companies in more environmentally responsible way. It also highlights the essential directions of design and content of the current and future environmental education and practice.

The methodology developed within the TrainERGY project and used in the research is also innovative. The calculation of covering index and presence index allowed to create an individual skill matrix for each researched country. The same methodology can be further extended to other European countries in order to create a Pan-European skill matrix.

The limitation of this research, can be a small number of respondents from particular countries what can limit the full comparative analysis. However the main purpose of this research project was to develop and pilot the skill matrix development methodology, thus wider studies are required in order to collect more comprehensive data.

The analysis provides empirical support for the development of meaningful competence development schemes for employees and managers, as well as guidelines for successful implementation of energy efficient and sustainable operations across Europe.

The findings from this research are also applicable to cross-cultural and cross-sectoral settings, and expand the existing institutional and supply chain management theoretical models with new variables, viable at the European level. The results of the survey is one

of the few attempts to address the competency gap mitigation for European companies and highlight to policy makers the necessary actions required to create an environment that promotes energy efficient and sustainable business activities.

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# IMPLEMENTING LEAN AND SUSTAINABLE CONCEPTS IN SMALL BUSINESSES

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## **Abstract**

### **Purpose of this paper:**

Modern companies strive to be as lean and sustainable as possible, yet sometimes this solutions are not so affordable. Small and medium companies have to due to the desire for competitive advantage in this highly demanding market, also introduce suitable tools to provide optimal lean and green to stay up to date and to ensure themselves the reputation of a successful business. As a case, we will present a Slovenian micro company to which storage and packaging process we have suggested some modifications from lean and green point of view. However, suggestions can merely be compared to the ones which could be introduced to large companies, yet could assure some vital progress from both point of views and represent some competitive advantage towards other Slovenian small companies.

### **Design/methodology/approach:**

First of all, our objectives will be achieved through literature review, where results from modern local and foreign literature will be presented. The practical part will constitute out of case study, from which a main result will be suggestions and modifications from lean and green intralogistics point of view.

### **Findings:**

Case study has after the recording of the intralogistics state revealed all of unhidden and hidden problems of a selected Slovenian micro enterprise in particular in terms of lean and green intralogistics. This led to several suggestions and also extensive discussion in which we have been discussing what do this kind of solutions mean to small business and do they help with gaining competitive advantage.

### **Value:**

There were only a few such case studies, also in Slovenia this is the first of its kind. The paper has value for academia researchers as well as for the economy. For researchers as it will provide additional case study in the field of small businesses, also some new topic insights and for the economy since it will provide indications and suggestions for leaner and greener intralogistics and overall small businesses.

## INTRODUCTION

In the last years, the so called small and medium sized enterprises (SME's) became a focal point of many researchers. The reason lies in the fact that there are numerous and usually economies backbone (Müller *et al.* 2007). SME's are defined by the European Commission as having less than 250 persons employed. They make up to 99.8% of all enterprises in the EU27, representing about 20 million companies employing almost 65% of total employees (Matt and Rauch 2013). The share of SME's in Slovenia is even higher. Slovenian statistical data (see Table 1) reveals that there are among the total of 114.184 companies almost 94 % micro (up to 10 employees) and approx. 5% small companies (10 to 50 employees).

### ***Percentage of companies by company size (%)***

Micro (up to 10 employees)	93.8
Small (10 to 50 employees)	5.1
Medium (50 to 250 employees)	1.0
Large (above 250 employees)	0.2
Together	100

Table 1: Percentage of companies by Slovenian statistical data of the Republic of Slovenia by company size (SURS 2013)

Due to their flexibility, the entrepreneurial spirit and the innovation capabilities SME's proved to be more robust than large and multi-national enterprises, as the actual financial and economic crisis shows (Matt 2007). In accordance with the mentioned and the importance of maintaining low costs in a bid to maintain the competitiveness was and is still nowadays of substantial significance. Consequently, companies are forced to examine every part of their organization for potential improvements. It is therefore not surprising that there are for SME's, mainly in the field of intralogistics many initiatives for possible improvements. We also have to acknowledge that the global logistics costs were estimated at USD 9,177 billion in 2015 (Armstrong & Associates 2014), so every failure, inconsistency or any kind of waste can represents great costs, especially for SME's.

One of modern SME's challenges besides eliminating non-value added activities in logistics processes is also assuring processes to be sustainable. The environmental aspect and ecological consciousness have increased drastically over the last two to three decades, especially in the developed economies. This has been shown by BearingPoint research (*Supply Chain Monitor "How Mature is the Green Supply Chain?"* 2008), where 35% of global companies said that they have incorporated a green supply chain policy in the company's vision. The impact of logistics management within SME's on environment is vast due to occupying land for transportation and storage, such as transportation access, consuming fuel, transport and storage equipment, generating wastes, producing loss and waste due to distribution processing, consuming material and the like. According to statistics of the "Internationale Energieagentur" almost one third of Carbone Dioxide (CO<sub>2</sub>) emissions are caused by transport activities which are also are closely related to logistics activities (Kranke 2008).

The area of SME's has been rarely exposed to research on lean and green logistics, most of them were in fact made in other fields, mainly in the area of lean manufacturing management. This study represents a contribution for both – academia and industry. For academia mainly due to the fact that this research will be the first of its kind and will take into account both paradigms, also their collaboration in the field of logistics. For industrials it will provide an insight on new trends and possible suggestions and contributions from each paradigm, especially their combination. Many researchers have focused on one phenomena rather than looking at them together. They have studied both philosophies separately, not often together and even more rarely, in the field of SME's.

The importance of joint research in this case is significant as it is the implementation of such a common system both, more efficient and has a double effect; it is cost-effective and environmentally – friendly.

## **REVIEW OF LITERATURE**

### **Lean logistics**

Taiichi Ohno as one of the beginners of lean thinking has in the 80's identified seven wastes - activities which add cost but no value: (1) production of goods not yet ordered, (2) waiting, (3) rectification of mistakes, (4) excess processing, (5) excess movement, (6) excess transport and (7) excess stock (Monden 1993). Since there are not only manufacturing and/or production created activities which add no value, industrials also started to put their focus on logistics non-value-added activities. From here on the new concept – lean logistics – appeared. Womack and Jones (1996) studied transformation of the Toyota US parts distribution system, back to the second-tier parts manufacturer of a replacement bumper and compared it with its system in Japan. Even Toyota saw lean improvements in logistics especially in the fields or within manufacturing, delivery, ordering, warehouse management, dealers and network structure. Lean logistics (2004) is a logistical dimension of lean manufacturing. Its primary objective is to deliver the right materials to the right locations, in the right quantities, and in the right presentation; its second to do all this efficiently. The same author continues that lean logistics could be and has been the concept applied to services, but they have focused on the manufacturing as a domain whereas it is rich in logistics concepts, approaches and techniques which can be addressed as lean because either they are part of the Toyota Production System or they were adapted from it for application in different contexts.

According to Jones, Hines & Rich (1997) lean logistics also takes its fundamental philosophy from the Toyota production system (TPS) and is based around extended TPS right along supply chains from customers right back to raw material extraction.

Since lean logistics systems brought logistics to a new level of efficiency, the latter enables faster delivery of goods to costumers which in contrast surely affects our environment. It is therefore an inevitable global trend to develop and adopt green logistics management in every sphere of national industry, especially in the production and transport sectors (Carter and Rogers 2008, Kovács 2008).

### **Green logistics**

During 1990s, environmentalism has been characterized as one of the most significant force shaping the economy (1995). Many articles based on concern for the environment have at that time also been written in the field of business and logistics (Dunning and Fortanier 2007, Günthner and Tenerowicz 2010).

The fundamentals of greening as a competitive initiative have also been discussed by (1995). Their basic reasoning was that investments in greening can be resource saving, waste eliminating and productivity improving. They state that green initiatives could lower not only the environmental impact of a business but also raise efficiency, possibly creating major competitive advantages in innovation and operations. Skjoett-Larsen (2000) wrote a foresight work upon European companies facing new challenges in the next millennium one of which is also green logistics. Nowadays, one of major issues for modern businesses is also an increasingly complex legislation with respect to environmental issues. The trust of many of these laws is to place the so called cradle-to-grave (CTG) responsibilities on companies for products and processes. The logistics discipline is well-qualified to deal with these CTG issues because of logistics' focus on supply chain management, which



emphasizes the control of materials from suppliers, through value-added processes and on to the customer (Marchet *et al.* 2014).

As concern for the environment is at this time crucial we also have to take into account lean logistics which aim is to satisfy customers' needs at the right time and at the right place with at least waste as possible. Modern lean logistics therefore uses sophisticated transport and manipulation equipment, modern technologies on logistics terminals and warehouses to secure lean supply chains. Combining all those elements and developing environmentally – friendly logistics is an issue which has been very topical in recent years.

### **Lean and green logistics**

Lean, according to (2006) is based on the assumption that time contractions reveal hidden quality problems and their solutions lead to improved, cost-effective business processes. The authors further contend that if time contraction implies to lower emissions, then as by the emissions measurements, a lean system is always greener. If the reduction of time does not lead to reduced emissions, it is necessary to find a way or further changes of the lean system to become greener. Researchers state that lean companies, which include green practices, achieve better lean results than companies which do not. Their findings indicate that only when both concepts are implemented simultaneously, they can disclose their full potential and make a greater contribution than if they were implemented separately. As such (Bergmiller and McCright 2009), emphasize that while lean practices can lead to positive environmental contributions, conversely environmental practices often lead to improved lean practices.

There are separate streams of research on lean logistics and green logistics, however few researchers explore some intersections of these two paradigms (Banawi and Bilec 2014, Garza-Reyes 2015). This represents a critical point for companies which are most likely missing opportunities for synergies that are available with improved simultaneous introduction and also may fail in addressing important trade-offs that may occur when there is incompatibilities between strategic initiatives.

Nevertheless, a waste of both paradigms is defined otherwise but both respectively target the removal of excess: the waste in the broadest sense. Lean logistics is focusing on removing 8 wastes related to efficient flow, while green logistics is focusing on green wastes in the form of inefficient use or waste production (Kleindorfer *et al.* 2005).

### **METHODOLOGY**

By reviewing international journals from both topics - green and lean logistics an analysis of previous research has been conducted. The search has been restricted to articles which contained specific keywords connected to lean logistics and green logistics in Emerald Online, Science Direct, Springer Link and Taylor and Francis portals. For the letter we decided to narrow our choices and only focus on international journal articles which contained specific keywords closely associated to lean logistics and green logistics. At the same time keywords containing 'supply chain', 'production' or 'manufacturing' were mainly excluded. The main reason lies in the fact that the aim was to narrow the scope of the research to a specific field – logistics rather than supply chain management or production and manufacturing. The practical part constitute out of case study, from which the main results will constitute out of suggestions and modifications from lean and green intralogistics point of view.

### **PRACTICAL EXAMPLE OF A SMALL SLOVENIAN COMPANY**

In this paper a practical example of a small sized Slovenian company to implement lean and sustainable concepts will be presented. The applied approach for implementation will be illustrated in a case study at a small sized company with 5 employees. A relatively young company sells water-aeration technologies for mostly wastewater treatment plants

and fish farms. The management wants to be prepared to benefit from the predicted upward phase of the market cycle and started a project to improve their internal logistics process management and warehouse facilities.

Considering the list of identified recommendable lean and green methods for SME's, was at the end of the research, and started the following lean and sustainable logistics project. The project was based on 5 different intralogistics areas: (1) internal logistics processes, (2) ergonomics and spatial planning, (3) human resources (upper management and employees), (4) strategic planning and (5) results associated with internal logistics.

SME's companies are very flexible and fast in their decision-making, but due to limited resources the people in this firm were not able to dedicate too much time for the project. Therefore it was better to work on such a project step by step. Time was a major and crucial factor in the implementation process. In SME's the implementation of an individual steps ends up on the shoulders of a single person, whereas in medium or large companies the work load is usually distributed on a team. After decomposition phase and the elaboration of a detailed realization plan, the concept was presented to the whole staff in an official kick-off-meeting. For company and its internal logistics system observation, 5 teams were assembled, each with a leader and a contact person within the company. For each area (working package) observations and suggestions have been made, also most of them already or still being implemented. The observations and suggestion are set out below:

(1) The first operative working package consisted of reorganization of internal logistics processes. During observation period, we have noticed that company's major issue was a lack of results monitoring and identifying causes and consequences of the problem. For the latter we proposed carrying out an accurate state analysis. We proposed the use of simple tools such as spaghetti diagrams, flow- chart diagrams, process charts, VSM and the like. This is crucial, because with them they are able to collect data for the internal logistics system state, especially the movement of materials, people and information, as well as identify opportunities for improvements, especially in the storage and transport system (also the administrative process). The latter forms the basis for quality monitoring results and identifying the causes and consequences of the problem.

For waste removal we also suggested that their business starts operating as much as possible by lean principles and adapt its processes in the most optimal, waste-free way. Helping to achieve this, we have suggested implementation of ISO 9001 standard for quality management, as well as ISO 14001 standard for sustainability.

(2) In the field of ergonomics and spatial planning we have noticed that the company's major issue lies in optimum distribution of the working space and sustainable building. The problem of optimal (also sustainable) spatial planning typically originates from the domain of involved investors and their economic interests.

When delivering the suggested improvements we have mostly relied on research Zavrtanik, Mlakar & Fatur (2009) which focuses on land use, process planning and specific aspects of development areas that are often not given enough attention or are being brought into the planning process at relatively late stages. The survey also provides guidelines for planning, regulation and management of other economic and logistic centers at the regional level. Modern guidelines optimal distribution of the workspace requires tracking of structural change, new technologies and the trend of globalization.

In the latter case it is necessary to take into account the four key aspects:

- environmental aspects in response to the preparation of an environmental report, which refers to a comprehensive environmental impact assessment;
- spatial aspect in accordance with regional and urban development;
- constructors technical aspect, ie. aspect of the functionality of logistic activities;

- economic aspect, the framework for the creation of investment value and its economic vitality.

(3) In the field of human resources (upper management and employees), companies major issues lie in the possibility of involvement of employees, long-term thinking, vision and involvement of employees.

The successful SME's companies should hold regular meetings with the management teams and, where necessary to discuss certain matters and to track the effectiveness with measurable behaviors for planning and demonstrating value. Execution of definitive measures to strengthen the commitment to the values of the organization and foster a culture that strives for efficiency. Increased efficiency in turn brings savings. The success of the organization, inter alia, depends on the commitment to implementing and maintaining a strong corporate culture. To strengthen the involvement of employees survey, Ref. (Axero b.l.) gives 49 ways you can improve the organization of the said area, which is also important from the point of view of a green and lean. Methods used by the organization Axero encourage employees to speak up, help get to know the employees with each other, the operation leaders as mentors to their employees, rewarding employees only for a job well done, focus on cooperation and joint work, the promotion of health and wellbeing, clarifying objectives and responsibilities required flexibility of employees, encourage employees to develop their careers, education and stared ahead like.

(4) In the field of strategic planning the results indicate that company's main challenges from this field lie in a strategy shared by all levels of the organization and other stakeholders and the introduction of the strategy. Many organizations spend a lot of time in responding to unexpected changes, rather than the latter and expects. The latter is in practice called the crisis management. Organizations can in this way consume a lot of time and energy. This leaves little time to prepare for future challenges.

For this reason, organizations must introduce good strategic planning, which is a suitable alternative to crisis management. The strategy, in so far as the organization wants to operate globally, must be shared with all levels of the organization. The strategy at only one level is not only inappropriate, but also ineffective. Different levels of strategic decision-making and design strategy must also include corporate, business and functional level.

(5) The last observed intralogistics field from lean and green point of view is results associated with internal logistics. Major identified issues in this field were constant monitoring of the results and identifying the causes and consequences of the problem.

For the issue of constant monitoring of the results, the main suggestion is building framework of the results. The framework presents the results of the strategy operating units to achieve a specific goal. Usually it is presented in a graphical form, supplemented with text. Box results include intermediate targets and results to be achieved, and also reflects the developmental hypothesis implicit in the strategy, and link cause and effect between results and objectives. This includes all of the critical assumptions that must adhere to the development hypothesis that leads to the achievement of the desired goal. To identify the causes and consequences we also suggest the use of basic tools such as cause and effect diagrams, fishbone diagrams, Ishikawa diagrams, herringbone diagrams and charts Fishikawa. To conclude, our basic key finding indicates the lack of tracking global trends, for example the introduction of ISO standards, favoring the acquisition of internationally recognized awards in the field of a green and lean. This would certainly have a positive impact on improving weaknesses within all five areas.

## CONCLUSIONS

SME's are as written in the introduction very important for the whole economy. This is also the case of Slovenia in which SME's are most widespread and also create most of the state industry sales turnover. Since they are so widespread, the state and EU created framework programmes for possibility of research, development and innovation projects mainly for SME's. The latter enabled many SME's to introduce improvement programmes for improving quality, productivity, leanness or sustainability. However, Ref. (Pejić 2016) research indicates that most small enterprises hesitate to make the move towards possible improvements, because they fear the needed resources in form of personnel, time and capital as well as the lack of know-how.

The case study showed in form of an action research in a small company with 5 employees, that introduction of lean and green logistics concepts is not only possible, it brought also improvements and advantages for the described company. Based on the results of this preliminary study, a wider research on a national level will be conducted.

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# **DYNAMIC CAPABILITIES IN THE USED CLOTHING SUPPLY CHAIN**

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## **ABSTRACT**

The purpose of this paper is to identify the dynamic capabilities present - and the ones missing - in used clothing supply chains. Such capabilities ensure ability to cope with the rapidly changing conditions in the used clothing supply chain, by creating, modifying and renewing the existing resource base. Particular empirical focus in the paper is given to fashion retailers and charities operating on the Swedish market. Based on the dynamic capabilities classes of sensing, seizing and reconfiguring, empirical data exemplify contemporary dynamic capabilities present among these actors. Theory on dynamic capabilities has to a very limited extent been applied in a reverse supply chain setting. The used clothing supply chain offers an interesting case for the exploration of the dynamic capabilities needed in such a reverse supply chain environment.

## **INTRODUCTION**

Driven by society's efforts towards environmental sustainability, the used clothing supply chain has in recent years received increased attention from practitioners as well as research scholars (Hvass, 2014; O'Reilly & Kumar, 2016). The used clothing supply chain typically includes fashion retailers, charity organisations, commercial trading companies and specialised sorting companies. It is a global supply chain, characterised by its diversity in terms of geographical coverage of its members, specialisation, and aims of participating companies. Along the tiers of this supply chain the donated waste clothes are recharged with new value for new purposes and customers, ranging from vintage high-street fashion to charity for people in need (Sandberg et al., 2016). In addition, retailers and their manufacturers also become customers to the used clothing supply chain as recycled textile fibres are increasingly included as raw material in new products. Major processes in this network of supply chain members include, but are not limited to, collection, sorting, re-processing, and re-distribution (Fleischman et al., 2004).

For included supply chain members it is necessary to ensure effective and efficient processes, in which the created value succeeds the associated costs for the supply chain members. To achieve this, previous research has shown that many used clothing supply chains increasingly apply and engage in new, innovative business models. For instance, Watson et al. (2014), investigating the Nordic context, mention leasing, the resell of used own-brand, clothing libraries, luxury second-hand shops, and specific repair services as new emerging business models that are all aimed at increasing the value creation. From a resource based perspective it could be argued that alignment of a suitable resource base is crucial for successful engagement of these business initiatives. Given the pace of

development both internally within these supply chains (e.g. in terms of new business models), but also a rapidly changing environment in terms of e.g. customer acceptance and demands, appropriate capabilities for development and change are vital. Such dynamic capabilities are the focus of this paper.

The purpose of this paper is to identify the dynamic capabilities present - and the ones missing - in used clothing supply chains. Dynamic capabilities theory is today a well-established research area originating from the Resource Based View of the firm (RBV), emphasising the need for continuous development and updating of the existing resource base. Dynamic capabilities are typically defined as "the capacity of an organization to purposefully create, extend, or modify its resource base" (Helfat et al. 2007, p. 4).

Research on dynamic capabilities in a reverse supply chain context has so far been sparse, and there is a need for more in-depth analysis and empirical evidence. Based on extensive research experiences, including empirical data from a large variety of different players within the used clothing supply chain, this paper could be considered as a first attempt to structure and gain knowledge in this area. Although it could be argued that dynamic capabilities are required along the entire used clothing supply chain, this research is geared towards the first part of the reverse supply chain, including fashion retailers and charities.

## **ON DYNAMIC CAPABILITIES**

Dynamic capabilities theory has during the last two decades become one of the most discussed topics in the strategic management literature. It has its roots in the resource based view of the firm and addresses the issue on how to maintain competitiveness, particularly in a volatile and turbulent environment. It is argued that in order to stay ahead of competitors and attract customers, a company's resource base must continuously be created, extended and modified (Kindström et al., 2013; Sandberg & Abrahamsson, 2011; Helfat et al., 2007). To structure the growing body of literature dealing with resources and capabilities, it has been suggested that these can be organised at different hierarchical levels (Winter, 2003), where a competitive advantage is ensured by static, momentary capabilities, sometimes referred to as operational capabilities. These explain "how we earn a living now" (Winter, 2003) at a given point of time (Teece, 2007) and are typically valuable, rare and difficult to imitate (Barney & Clark, 2007). To sustain the competitive advantage over time, these operational capabilities need however to be coupled with dynamic capabilities that are aimed at the creation, extension and modification of these operational capabilities (Helfat et al., 2007). In recent years dynamic capabilities theory has also gained attention in a supply chain context (Sandberg & Abrahamsson, 2011; Defee & Fugate, 2010), particularly stressing the fact that dynamic capabilities may not only be an internal affair, but should also include the supply chain as a whole.

As a means to structure the analysis in this paper, the three influential dynamic capability classes of sensing, seizing and reconfiguring presented by Teece (2007) will be elaborated below. Drawing on earlier work such as the exploration-exploitation dichotomy and market orientation research (Kohli and Jaworski, 1990), the dynamic capabilities framework by Teece (2007) structures a comprehensive amount of so-called microfoundations, defined as "distinct skills, processes, procedures, organisational structures, decision rules and disciplines" (Teece, 2007, p. 1319).

*Sensing capabilities* typically include the scanning, learning and interpretation activities of a company (Teece, 2007). Exploration of global as well as local markets and customers' preferences, including for instance identification and understanding of customer needs in a sense of "intelligence generation" (Kohli & Jaworski, 1990) are here important. A subsequent dissemination of such information is also part of the sensing capability. Apart from the market sensing activities, and particularly noticed in logistics research context, also the capturing of ideas internally within the company, e.g. from employees are important sensing capabilities (Esper et al., 2007). In a logistics context the sensing capabilities in the supply chain, i.e. between different companies have been highlighted. For instance, Defee & Fugate (2010) present a knowledge accessing capability that is concerned with the understanding of other supply chain members' knowledge base.

As argued by Teece (2007), once a company has sensed a new business opportunity, it must also be seized adequately. A condition for *seizing capabilities* is a business model that can sustain and exploit new opportunities as they occur (Kindström et al., 2013). Thus, the company must be able to capture the business opportunities at hand. These business opportunities are realised in new products, processes and offerings.

Finally, beside sensing and seizing capabilities Teece (2007) present *reconfiguring capabilities* as a third group of dynamic capabilities that are geared towards more fundamental change of the resource platform that continuously sense and seize business opportunities. Thus, such more substantial changes in the resource base aim at improving future sensing and seizing abilities. An important concept related to reconfiguring capabilities, and stressed in a logistics research context, is organisational learning capabilities (Esper et al., 2007; Sandberg & Åman, 2010), focusing on the ability of a company (or supply chain) to accumulate, articulate and codify knowledge within the company.

## **METHODOLOGY**

In this working paper, the analysis is based on a larger data collection set with interviews, field visits, and secondary data. Data collection was mainly conducted during 2015-2017. The data incorporates actors in the entire used clothing supply chain, stretching from retailers and charities at the front-end towards consumers (and donators) to recyclers and specialised sorting companies in multiple tiers in the supply chain. Particular attention in this paper is given to the practices at charity organisations and fashion retailers operating on the Swedish market. As such, the Swedish context could here be considered well-developed, full of examples and initiatives of pioneering new business models and other attempts to develop the market (e.g. Watson et al., 2014).

Empirical data presented in this paper has mainly been used to exemplify contemporary dynamic capabilities present among these actors, and the paper does therefore not include an exhaustive data presentation. Based on Teece's (2007) framework on dynamic capabilities classes, current capabilities are elaborated in the analysis of the paper. Inspired by each of the three classes in turn, the analysis can be described as explorative and inductive, extending the body of existing literature in the area (Ellram, 1996). Not an exhaustive list of capabilities has been searched for, but rather rich, illustrative examples from each class.

## **FASHION RETAILERS AND CHARITY ORGANISATIONS**

The Swedish charities and retailers investigated in this study are part of a complex, globally stretched network with a mixture of profit- and non-profit making companies, different relationships in terms of degree of collaboration, size of the companies involved, etc. Below follows a short description of the two investigated actor-types focused in this research, i.e. charities and retailers.



Driven mainly by consumer pressure on environmentally friendly businesses, the involvement in the used clothing supply chain is slowly considered to become a source for competitive advantage for fashion retailers. The retailers are typically involved in collection processes of donated clothes, e.g. via take back schemes. Given their physical store position in the city centres and shopping malls, retailers hold a convenient place for the collection of used clothes. Advertisement campaigns, hand-outs of vouchers to buy new clothes if returning old ones, etc. are other initiatives driven by the retailers. Most of them today collaborate with either a charity organisation or a profit-making commercial retailer regarding collection process. For instance, collection boxes situated in the retailers' stores are often managed and controlled by the collaboration partners. Retailers normally strive towards a zero-sum game when it comes to economic profit of their involvement in the collection processes. There are situations where the retailers get paid for the clothes (often price per kilo) as well as situations when the retailers pay or take extra costs for the collection of clothes. Instead of economic profit improved environmental image towards end consumers are strived for (Sandberg et al., 2016).

Charity organisations, having traditionally been the major collaboration partner to the retailers, have in recent years faced competition from larger, multinational commercial recycling companies regarding their collaboration with the retailers. The commercial recyclers main advantage vis-à-vis the charities is above all to be found in their more comprehensive offering in the partnership. Utilising a global network of sub-suppliers they are able to offer the retailers a life-cycle based approach to used clothing, including both collection and sorting, but also supply of recycled fibres to the retailers' factories.

Charity organisations operating in Sweden still play a major role in used clothing supply chains in Sweden. Their operations normally covers collection (sometimes in collaboration with retailers), sorting, remanufacturing, sales of clothes to consumers as well as to other "wholesale companies" (e.g. recycling companies and specialised sorting companies), and, perhaps most important, distribution of clothes to people in need (in the domestic market as well as development countries) (Sandberg et al., 2016). Charity organisations' second hand retailing business has in recent years grown in importance. Today, apart from traditional second hand consumers aiming at low price with an environmentally friendly attitude as an extra bonus-value, a category of "high-street fashion customers" looking for unique, personal products, typically branded, vintage clothes of high quality has emerged. This customer group, far less price sensitive than traditional second hand consumers, are met with new stores placed at expensive shopping avenues in larger cities in Sweden.

In line with existing research (e.g. Bernon et al., 2011), decisive for successful business in terms of economic gains is a cost efficient sorting process. In addition, this process needs to be effective in terms of value extraction, i.e. a proper match between supply and demand is required.

## FINDINGS

Table 1 below summarises the findings of the analysis.

	Charity organisations	Fashion retailers
Sensing capabilities	Swedish Red cross: Education of personnel in fashion trends at the sorting facility to improve sorting effectiveness. In collaboration with Swedish fashion council.	H&M: Partnering with Hong Kong Research Institute of Textiles and Apparel about technology solutions on recycling of fibres, increasing H&M's ability to scan and evaluate new research and technologies.
Seizing capabilities	Emmaus and Myrorna: Inventory based on dynamic stock keeping units, which means that a unique product can simultaneously be group into different categories. As a result, effectiveness of the matching process is thereby improved.	Linex: Initiated a collaboration project with designers, researchers and local producers to launch a completely new collection of clothes entirely based on reused materials. Complements their ordinary assortment, improves their image, and increases their hands-on experience on redesign.
Reconfiguring capabilities	Stadsmissionen: Improved organisational learning processes, in which new knowledge is systematically accumulated, articulated and codified in the organisation to increase efficiency in sorting facility.	N/A

**Table 1 Summary of the findings**

### **Sensing capabilities**

In a rapidly changing environment in terms of customer demands, shorter fashion cycles, and decreased brand loyalty among consumers, it is vital to match the product offering with the instant demand of customers. In a used clothing supply chain, in which the products typically are characterised by a huge variety and small series (to a large extent unique products), the ability to "offer the right product to the right customer, in the right moment" is crucial. To ensure this, sensing capabilities are needed. The empirical data provide at least two examples of sensing capabilities related to the charities' sorting process, which is critical for enhancing value creation in the entire supply chain.

First, the Swedish Red Cross has improved their market sensing capability by educating their sorting personnel about contemporary fashion trends. By this education, which is done in collaboration with the Swedish Fashion Council and municipalities, the effectiveness and knowledge of the sorting process, i.e. the matching process between supply and demand, is expected to increase. Second, another approach for an improved matching process between supply and demand in the sorting process could be labelled "demand-driven sorting", in which the Swedish second-retailers connected to the charities (e.g. Emmaus and Myrorna) have invested in quick, automatized sorting system like conveyors to minimize handling thus improve sorting speed. Building on years of experience, the sorting team has developed colour maps, price segments and grading capabilities which allow categorizing items based quality (level of dirtiness, stain etc.) and demand for various destination markets and industries (e.g. recycling, rag, second-hand clothes etc.)

A major challenge in the entire used clothing supply chain is to already in the design phase be able to select raw materials and production processes in such a way so that recycling of fibres is facilitated. In fact, to this date there is no commercially viable separation, sorting and recycling technology for materials such as cotton and polyester blends. In order to improve their expertise in this area, and ability to scan and evaluate new research and technologies, H&M has partnered with the Hong Kong Research Institute of Textiles and Apparel. From a dynamic capabilities view, this collaboration could be seen as an example of H&M's knowledge accessing capability (Defee & Fugate, 2010). In short, the knowledge accessing capability underscores the fact that in a dynamic environment an individual company will not be able to keep all possible knowledge in-house. Rather, the company needs to know where to get access to appropriate knowledge when needed (Defee & Fugate, 2010).

### **Seizing capabilities**

To successfully match supply with instant demand from customers not only sensing capabilities are needed, but also seizing capabilities (Teece, 2007). One such capability applied at the participating charity organisations (Emmaus and Myrorna) is the introduction of dynamic stock keeping units, SKUs. This means that the same unique product can be marketed in different settings in the company's sales promotions. In particular more expensive products, e.g. a jacket, could be defined as a jacket, seasonal jacket, vintage jacket, branded jacket or something else. Overall, this simple yet demanding way of categorising products enables a larger "interface" towards potential buyers, i.e. the matching process between supply and demand becomes more effective.

According to Teece (2007) an important microfoundation for adequate seizing capabilities is a business model able to seize the business opportunities that are sensed. The empirical data from this research confirms the importance of new business initiatives taken individually by the included companies in the used clothing supply chain, as well as in collaboration with each other. A general capability identified in the study to ensure

new business initiatives to be taken is the ability of participating companies to rapidly engage in new business relationships. For example, the Swedish fashion retailer Index has recently engaged in a collaboration with designers, researchers and local producers to launch a completely new collection of clothes entirely based on reused materials. This new collaborative relationship hence enabled a new type of product for the retailer, complementing their ordinary assortment and attracting new customers as well as strengthening their brand image towards sustainability. In addition, new knowledge and "hands-on" experiences regarding redesign was gained. From an academic perspective, this initiative could be considered as an example of a supply chain dynamic capability labelled co-evolvment, defined as "the set of routines businesses use to reconnect webs of collaborations within and across companies to generate new and synergistic capabilities" (Defee & Fugate, 2010, p. 190).

### **Reconfiguring capabilities**

Driven by the sustainability focus in the used clothing supply chain, fashion retailers as well as charity organisations acknowledge a growing need for domestic handling in the reverse supply chains, typically including sorting and remanufacturing/redesigning activities, at least for the products that are to be sold at the Swedish market. It is suggested that such a domestic supply chain would further strengthen the sustainability image and at the same time enable more rapid development of customer-unique, new products (through re-design initiatives). However, in order to expand domestic sorting, re-design and re-manufacturing processes further, cost efficiency improvements are needed. Of particular importance are efficient sorting processes and facilities. In fact, a recent report from Swedish researchers (Carlsson et al., 2015) indicated that a full-sale commercially run sorting facility is not possible in Sweden due to the high costs associated (mainly related to high wages). The ones today operated (mainly by charities) all enjoys different types of governmental subsidies or are based on a voluntary working force.

Despite this challenging situation, several initiatives based on reconfiguring capabilities have been conducted in recent years, aimed at improving cost efficiency in sorting facilities. In the very centre of these efforts are improved learning processes, a key microfoundation in Teece's (2007) reconfiguring capabilities class. For instance, the charity organisation Stadsmissionen, running a major sorting facility in Sweden, stresses the need for proper organisational learning processes, in which new knowledge are systematically accumulated, articulated and codified in the organisation (Sandberg & Åman, 2010). Engaging many short-term employees in their sorting facilities, these processes are identified as important for cost efficiency reasons. Related to the need for improved organisational learning processes, issues on how to accumulate and exploit valuable knowledge and know-how from refugees and other people moving in to Sweden has been raised. Standardised, introduction programmes and simple, yet clear routines are identified as especially important, meanwhile the new employees' existing knowledge and know-how is utilised.

### **CONCLUSIONS**

Based on the dynamic capabilities framework with sensing, seizing and reconfiguring capabilities, this paper elaborates different types of dynamic capabilities that are present in existing used clothing supply chains. Particular focus is given to fashion retailers and charity organisations operating at the Swedish market. As a means to accomplish successful used clothing supply chain practices, this paper has argued that appropriate dynamic capabilities are necessary. These capabilities ensure ability to cope with the

rapidly changing conditions in the used clothing supply chain, and create, modify and renew the existing resource base (Helfat et al., 2007).

In accordance with the purpose of this paper, missing dynamic capabilities are also identified. Although the explorative findings presented in this paper need some further empirical evidence, a striking finding is the absence of reconfiguring capabilities among fashion retailers. Whereas charities demonstrate an openness and willingness to make larger changes in terms of e.g. investments and knowledge building, mainstream fashion retailers seem to lag behind in this capability category. An exception might be smaller, new fashion retailers (often with a clear sustainability profile). In this group we are aware of a larger willingness towards efforts in the used clothing supply chain. However, the mainstream, larger fashion retailers as has been focused in this study, we see little of this kind of capability. In the future, we judge reconfiguring capabilities among these retailers to be more important. In order to improve their environmental image, initiatives taken in used clothing supply chain practices could be considered as a complement to the previous, more established, sustainability efforts towards suppliers in the traditional, "forward" supply chain. Thus, reconfiguring efforts in the used clothing supply chain could be seen as a logical next step for many retailers (Hvass, 2014; Jayaraman & Luo, 2007; Sandberg et al., 2016).

Theory on dynamic capabilities has to a very limited extent been applied in a reverse supply chain setting. The used clothing supply chain offers an interesting case for the exploration of the dynamic capabilities needed in such a reverse supply chain environment.

Although this explorative paper is limited to short empirical examples, they feed into a number of promising future research topics. In particular, these are related to the fact that a majority of the identified capabilities are coupled with collaboration, i.e. the capabilities are built upon interorganisational collaboration among included members of the used clothing supply chain (primary as well as secondary actors such as research organisations). Overall, sustainability efforts in the used clothing supply chain seem to a large extent be built upon collaborative initiatives, here identified as dynamic capabilities. Therefore, dynamic capabilities on a supply chain level, pioneered in a logistics research setting by for instance Defee & Fugate (2010), here seems to be a promising future theoretical lens for more in-depth studies. Defee & Fugate's (2010) two main classes, knowledge accessing and co-evolvement, as have been discussed previously in this paper, could here serve as a fruitful starting ground. Another interesting future research topic also related to collaboration would be to further explore more specific drivers and barriers related to the different collaboration efforts.

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# **IMPACT OF LEAN MANUFACTURING AND INNOVATION ON ENVIRONMENTAL PERFORMANCE; MEDIATING ROLE OF SUSTAINABILITY PRACTICES**

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## **Abstract**

**Purpose** - This research investigates three distinct (often conflicting) supply chain paradigms (Lean Manufacturing, Environmental Sustainability and Innovation) together to explore the 'black box' (knowledge void) of integration. Organisations are facing with increasing pressure to be sustainable in their operation along with the need to be innovative and cost effective. The integration of these variables is important for the advancement of operations management literature and to the manufacturing industry. The research investigated the mediating role of green practice between innovation and environmental performance. It also investigated whether the effect of lean practices on environmental performance is mediated through green practices.

**Methodology** - A conceptual model is built along with several hypotheses to assess individual relations among the variables. Using Partial Least Square Structural - Equation Modelling (PLS-SEM) with the quantitative survey data collected from the UK manufacturing industry, this study examined the conceptual model and individual hypothesis.

**Findings** - The study found that the magnitude of green practices sequentially mediates the relation between innovation and environmental performance and between lean and environmental performance. It also found that the integrated model is validated where lean, green and innovation affect organisation's environmental performance.

**Originality** - Existing literature discussed these paradigms individually or have looked at other integration model implicating lean and green. Very few (if any) examined these relations simultaneously and validated the model by empirically evaluating them. This research can also be a reference point for the managers to strive for a leaner, greener and innovative manufacturing.

**Limitations** - There are several limitations of this study. Firstly, the sample size is small which could hamper the generalizability of the study. Secondly other performance indicators such as marketing performances, financial performances were not accounted for in the study. Thirdly, the data were collected only from the manufacturers and not from the suppliers or distributors. And fourthly, the study used a conceptual scale for environmental performance with a 5 point Likert scale. Factual data from the organisations would have been ideal to truly reveal the extent of improvement in terms of numbers and ratios

## **1.1 Introduction**

Around the world, 174 countries signed the Kyoto Protocol to address the detrimental effect of carbon emission on the environment (UNFCCC, 2016). The protocol entails that the industrialist nations take more burden in curbing these effects. In the 2nd implementation stage from 2012 to 2020 all developed nations including UK are committed to reduce the emission up to 18% of the 1990 level (IPCC, 2013). Recently, the Paris Agreement on keeping the global temperature under 2<sup>o</sup>C in this century has been ratified and came in to effect in the Marrakech summit 2016 (UNFCCC, 2016). The Resource Based View (RBV) entails the competitive edge of organisation's resources where these resources constitute the basis of competitive advantage. Drawing on this organisational theory, this research examined the integration of three distinct supply chain paradigms Lean, Sustainability and Innovation so that organisation's resources are utilized in the most effective way. The integrated approach can offer great return where innovation, reduction of cost, waste minimization culture and environmental thinking are viewed as part of a same strategy that can facilitate competitiveness and innovation in the value chain (Porter and Van der Linde, 1995; Kramer and Porter, 2011). Recent literatures focused on the individual paradigm (lean, green or innovation) or looked at the relationship of other variables such as agility, resilience, supply management, marketing and financial performance, human resources (Mollenkopf et al. 2011; Carvalho et al. 2012; Yang et al., 2011; Jabbour et al., 2013), inbound-outbound logistics (Prajogo et al., 2016). Absent in the literature is the study of the integration of lean, green and innovation simultaneously to answer whether they can be combined and what happens when they are combined. A conceptual model is built to test their combined effect on firm's environmental performance. Eight hypotheses were developed from literature discussion to investigate individual relations among variables.

### **2.1- Lean management and environmental sustainability**

Previous researches have indicated that lean manufacturing encompasses a set of inter-related tools such as JIT, TPM, Kaizen, TQM etc. often mentioned as lean bundle which mainly aims to eradicate wastes (non-value added tasks) from the entire value stream of a product (Shah and Ward, 2003, 2007). It is also suggested that lean manufacturing techniques can reduce customer lead time, cost and manufacturing cycle time. Hart (1995) concluded that manufacturing practices significantly contributes to the environmental performance through product design and process technologies. Florida (1996) investigated the relation between lean and green practices and indicated that the tireless pursuit of waste minimization of the lean practices leads to better environmental performance. Waste is a common denominator for both lean and green management (Porter and van der Linde, 1995; Hajmohammad et al. 2013). Lean management strives to achieve 'Zero defect manufacturing' and thus reduce operational wastes in the form of waste generation and carbon emission in manufacturing, reduction of energy, water and air use to contribute in augmenting environmental performance (King and Lenox, 2001; Bargmiller and Mcright, 2009). Rao and Holt (2005) established a positive link between greening the outbound supply chain and competitiveness, as measured by efficiency, quality, productivity, and cost savings. In a later study, Zhu et al. (2008) have shown that in addition to the link between green supply chain practices and inventory levels, product quality, product line, and capacity utilization, there is also a link between green practices and environmental and economic performance.

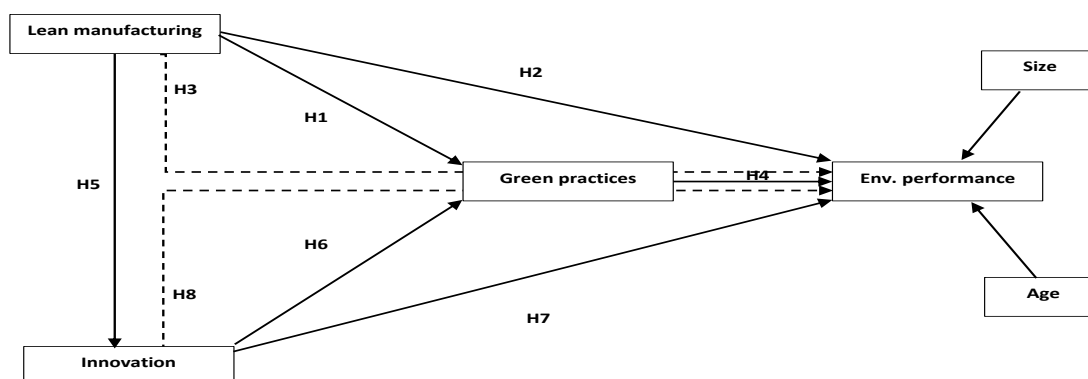


Figure 1- The Hypotheses and conceptual model, (Plant 'size' and 'age' as control variable).  
Therefore, we hypothesize

*H1- Lean manufacturing practices have a positive effect on green practices.*

*H2- Lean manufacturing practices would have a positive effect on environmental performance.*

*H3-Green practices mediate the relation between lean manufacturing and environmental performance.*

## 2.2- Environmental practices and performances

A close review has indicated a positive relation between environmental practices and environmental performance. Hart (1995) extended the Resource Based View RVB to Natural Resource Based View NRBV suggesting pollution prevention, product stewardship and sustainable development as the strategies to achieve competitive advantage. Klassen and Whybark (1999) also found a strong relation between environmental investment on environmental technologies and environmental management orientation through the adoption of environmental technologies, pollution prevention and management system. Emission reduction techniques were shown positively related with organisation's performances (Hart and Ahuja, 1999). Internal environmental management along with external environmental management and eco design were found to be affecting the environmental outcomes of the company which includes reduction in the carbon emission (Zhu et al. 2005; Zhu et al. 2008). In a different study, Zhu and Sarkis (2004) discussed the relationship between the early adopters of the green practices and organisation's environmental performances. Greening the outbound and inbound functions leads to a better competitiveness and environmental outcomes (Rao and Halt, 2005). Green practice of environmental auditing system EMAS was found affecting the environmental performance (Iraldo et al. 2009). Therefore, we hypothesize,

*H4. Green practices would be positively connected to environmental performance.*

## 2.3- Lean manufacturing and innovation practices

Product and process innovation is now regarded as one of the key factors for gaining competitive advantage over the competitors and the shift of individual organization competitive to the competition between supply chains is one of the reason that the supply chains needs to adhere to the innovation process. Continuous improvement of capabilities and resources and exploitation of opportunities has been termed as innovation (Szeto, 2000). The culture of continuous improvement instils the product and process innovation. Soltero and Waldrup (2002) compared continuous improvement with a two-wheel cart where one wheel is Kaizen and the other is innovation which eventually connects the pollution prevention techniques for both financial and environmental performances. The use of visual control, quality control at source and JIT systems have transformed the plant management in recent years and these transformations propelled the development of work innovations (e.g. enhanced technique, job rotation and continuous improvement activities)



in the firm (Cooney, 2002). Allen and Wigglesworth (2009) studied the pharmaceuticals industry in the light of the integration of innovation and Lean Sigma design, where they concluded that the lean sigma (by implementing the DMAIC process for six sigma and value stream mapping, scheduling etc.) would significantly reduce the cycle time in the sample management of the pharmaceutical industry and would bring in product and process innovation in the system as required by the new way of doing business in an lean environment.

*H5- Lean production practice would be positively associated with organizations innovation.*

## **2.4- Innovation, green practices and environmental performance**

Several researchers have investigated the green/environmental innovation and organizations performance (e.g. Cainelli et al. 2011; Gonzalez-Benito and Gonzales Benito, 2005) whereas other studies (Cheng et al. 2014; Cuerva et al. 2014) looked at the firm-level green innovation. Integration of environmental sustainability and innovation can really boost the environmental performances by energy savings, cost reduction, increased reputation and image. Cuerva et al. (2014) investigated the drivers of eco-innovation in the SME industries and found a strong connection of quality management system QMS and eco-innovation. Eco-innovation can also be seen improving product and process for energy saving, pollution prevention, waste minimization, green consideration in the design and packaging to achieve competitive advantages (Cheng et al. 2014; Porter van der Linde, 1995, Hart, 1995). Porter and van der Linde, (1995) pointed that eco innovation can yield better environmental performance by reducing wastes and pollution by engaging environmental thinking in product and process innovation. They also put forward the notion that eco-innovation leads to both economic and environmental gain and can allow a win-win situation for both the organization goals. Laforet, (2013) investigated the organizational innovation outcomes in the SMEs and concluded that organizational innovations lead to enhanced productivity and does not have an adverse effect on the environment rather in the case of the SMEs organizational innovation culture boosts the environmental performance of the organization. Chen et al (2003) developed an environmental model of Quality Function Deployment (QFD) called QFD for Environment (QFDE) where they integrated environmental engineering and environmental voice of customer (VoC) into QFD to ensure traditional and environmental quality requirement for applying them in the early stage of product design or new product development (NPD). Sustainable innovation can be applied to product innovation (efficient product), process innovation (Less input in the system) and organizational innovation (management tools) to achieve the desired results of improved production and operating system that provides economic as well as environmental benefits (Rennings, 2000; Rennings et al. 2006). Therefore, we propose,

*H6- Organization's Innovation practice would be positively related to Green practices.*

*H7- Organization's Innovation practice would be positively related to Environmental Performances.*

*H8- Green practices mediate the relation between innovation and environmental performance.*

## **3.1- Methodology and Construct building**

A database of 14000 UK manufactures was used. 800 manufacturing plants were randomly selected for e-survey. Out of this process, 101 responses were collected from December 2016 to February 2017. 8 questionnaire were discarded as they are only partially filled leaving 93 usable responses. Survey research instrument was designed according to our constructs. This research adopted an e-survey and an online platform was created in Survey Monkey where 50 items (based on 4 main constructs lean, green, innovation and environmental performance and 2 control variables 'age' and 'size') were developed in the process based on literature review and previous researches. Structural Equation Modelling (SEM) was used to evaluate the relations and the model. Structural equation modelling is a tool for evaluating the relations between concepts and for testing the model. Lean manufacturing construct was built based on a set of tools prescribed in the lean literature. 16 questions were set on the lean practices like Value stream mapping, Just in time, total

preventive measures TPM, visual control, 5S, quality measures and continuous improvement. A five point Likert scale was used to see the variability. Green construct was built on the green practices discussed in the literature. Environmental management system EMS engagement was investigated through their ISO14001 adoption status. Questions were also set on the other practices like design for environment, 3Rs, LCA, disclosure of the information, collaboration with suppliers and other stakeholders. 14 questions were set on a 5 point Likert scale. Innovation construct was built on the innovative practices based on the theoretical discussion in the literature review. The review revealed that the product and process innovation were the dominant discussion in the literature. 9 questions were set on a 5 point Likert scale to investigate the variability. Questioned were asked on their new product development NPD, new process development, technology sharing and on the state of the R&D of the organisation. Lastly the Environmental Performance construct was also built on a 5 point Likert scale and 6 items developed in the questionnaire. questions were set on the reduction in the emission, water, energy and material usage, improvement in the pollution prevention and controlling techniques. Partial Least Square based SEM calculation was adopted using SmartPLS 3.0 (Ringle et al. 2013) software (a 2<sup>nd</sup> generation SEM software based on PLS Algorithm).

### 3.2- PLS-SEM data calculation

PLS is a variance based approach compared to the covariance based SEM. Wold (1974,1980, 1982) originally developed the PLS-SEM approach. A CB-SEM approach determines how well the model estimates a covariance matrix whereas the PLS works much like a multiple regression based on a path model (Fornell and Bookstein, 1982; Rigdon, 1998; Hair et al. 2011).

**Table 2- Reliability and Validity**

	Composite reliability	AVE	Cronbach's Alpha
AGE	1	1.000	1.000
ENV. PERFORMANCE	0.931	0.694	0.912
GREEN	0.956	0.591	0.950
INNOVATION	0.930	0.654	0.911
LEAN	0.966	0.653	0.962
SIZE	1.000	1.000	1.000

**Table 3- Heterotrait-Monotrait Ratio HTMT**

	AGE	ENV. PERFORMANCE	GREEN	INNOVATION	LEAN	SIZE
AGE						
ENV. PERFORMANCE	0.075					
GREEN	0.151	0.870				
INNOVATION	0.112	0.810	0.890			
LEAN	0.192	0.763	0.837	0.810		
SIZE	0.419	0.371	0.423	0.420	0.337	

In the PLS based approach, the parameters are obtained from the sample data that best predict the endogenous constructs compared to the CB-SEM approach where the goal is to minimise the difference of the sample covariance matrix and the covariance matrix implied by the model. Small data size is one of the main reasons that researchers use PLS (Ringle et al. 2011; Ringle and Sarstedt, 2016). Hair et al. (2014) suggested a 3 steps procedure for the PLS calculation. First the model needs to be specified. The specification involves designing the inner and the outer model. Second, the evaluation of the outer model and lastly, the evaluation of the inner model. First, the analysis of the Reliability and Validity of the data were checked. Composite reliability and Cronbach's Alpha were tested where all items scored above the threshold 0.70 showing good reliability (Table 2). 2 items were dropped in the process due to Cross or Low loading. Next, convergent and discriminant validity was checked. Average variance extracted AVE is checked where all values were more than 0.50, showing convergent validity. Strong loadings of the items (more than 0.70) are also a sign of convergent validity in our model (Hair et al. 2014). A new criterion for discriminant validity proposed by Henseler et al. (2015) for SEM calculation,

Heterotrait-heteromethod Monotrait Heteromethod (HTMT) was used which shows all value under 0.90 (Table 3) confirms the discriminant validity of the study. 1 item was dropped at this stage to improve HTMT. Collinearity was also checked for Multicollinearity problem both in the Inner and Outer models. We checked the Variance Inflation Factors (VIF) values in both models which were less than 0.50, showing that collinearity is not a problem in our study. The inner model (Structural model) explains the relationships between the variables. Unlike the CBSEM where a well-accepted goodness-of-fit measures exists, in the PLS calculation does not have a standard goodness-of-fit index. Rather the model is evaluated by the (a). Coefficient of Determination  $R^2$ , (b). Cross validated redundancy  $Q^2$ , (c). Path coefficient  $\beta$  and (d). Effect sizes  $F^2$  (Hair et al. 2014).

**Table – 1 Path coefficients and Significance**

PATH COEFFICIENTS						
	Original Sample	T Statistics	P Values	F <sup>2</sup> squared		
AGE -> ENV. PERFORMANCE	-0.077	1.256	0.210	0.015		
<b>GREEN -&gt; ENV. PERFORMANCE</b>	<b>0.546</b>	<b>3.654</b>	<b>0.000</b>	0.223		
INNOVATION -> ENV. PERFORMANCE	0.149	1.244	0.214	0.020		
<b>INNOVATION -&gt; GREEN</b>	<b>0.528</b>	<b>5.926</b>	<b>0.000</b>	<b>0.492</b>		
LEAN -> ENV. PERFORMANCE	0.172	1.314	0.189	0.030		
<b>LEAN -&gt; GREEN</b>	<b>0.401</b>	<b>4.293</b>	<b>0.000</b>	0.283		
<b>LEAN -&gt; INNOVATION</b>	<b>0.763</b>	<b>13.506</b>	<b>0.000</b>	<b>1.392</b>		
SIZE -> ENV. PERFORMANCE	0.043	0.583	0.560	0.004		
<b>Variance explained in the endogenous variables</b>						
Environmental performance	R <sup>2</sup> 0.692	<b>Q SQUARED</b>		SSO	SSE	Q <sup>2</sup> (=1-SSE/SSO)
Green practices	R <sup>2</sup> 0.763	AGE		93	93	
Innovation	R <sup>2</sup> 0.582	ENV. PERFORMANCE		558	312.428	<b>0.440</b>
<b>SRMR</b>		GREEN		1395	825.438	<b>0.408</b>
Saturated Model	0.070	INNOVATION		651	424.074	<b>0.350</b>
Estimated Model	<b>0.073</b>	LEAN		1395	1395.000	
		SIZE		93	93	

The Coefficient of Determination  $R^2$  measures the predictive accuracy of the model. It measures the combined effect of the exogenous constructs on the endogenous construct and ranges from 0 to 1. A rule of thumb is that  $R^2$  value 0.25, 0.50 and 0.75 are termed as weak, moderate and substantial effect on the endogenous constructs (Hair et al. 2014). Our analysis showed a strong predictive accuracy for the three endogenous variables giving the value 0.69, 0.73 and 0.58 for environmental performance, green practices and innovation respectively (Table 1). The Stone-Gessier's (Stone, 1974; Geisser, 1974)  $Q^2$  assesses the structural model Predictive Relevance by calculating the Cross-validated Redundancy. The process involves a *Blindfolding* procedure where certain section of the data matrix in the sample is omitted and estimates the model parameters and then predicts the omitted part using the parameters estimation. Table 1 shows the Q squared value more than 0.35 for all the endogenous construct confirms the predictive relevance of our model. On the other hand, Cohen's (1988)  $F^2$  measures the effect size of each path model where the  $F^2$  squared is calculated by evaluating the change in the  $R^2$  value when a construct is omitted from the model. The PLS software creates two model to calculate  $F^2$ . The first model is a full model with all the constructs and in the second model one construct is omitted and  $F^2$  is calculated by the difference of the Included model and excluded model. The effect size of the deleted exogenous construct on an endogenous construct can be weak, moderate and substantive effect with the values 0.02, 0.15 and 0.35 respectively (Hair et al. 2014). Table 1 shows the effect sizes of all construct relations where innovation-environmental performance and lean-environmental performance were found to have weak effect. The hypothetical connections between the exogenous and endogenous constructs are estimated by the path coefficients denoted by  $\beta$ . PLS algorithms does not produce the standard error. Therefore, a *Bootstrapping* procedure need to be adopted to obtain the

standard error to investigate the significance level. *Bootstrapping* procedure is an iterative procedure where the software produces subsamples from the original sample and runs an iterative process (5000 times prescribed in the literature). It uses the t test to obtain the significance level of the hypothesized relations. T values of 1.65, 1.96 and 2.58 are associated with the significance level at 10% (0.10), at 5% (0.05) and at 1% (0.01) (Hair et al. 2014). Our structural model was evaluated and the analysis (table 1) strongly supported H1 and H4 with  $\beta = 0.401$  and  $\beta = 0.546$ , both with P value =  $<0.001$ , H5 and H6 were also supported with  $\beta = 0.763$  and  $\beta = 0.528$  both with significance level  $<0.001$ . H2 and H7 were not supported as the relations were not found significant. Finally, the Standardised Root Mean Square Residual SRMR value was 0.073, less than the cut-off point 0.08 showed the model fits with the data.

Hypothesis H3 and hypothesis H8 were checked for the possible mediation effect of the green practices. First the direct path between innovation and environmental performance was calculated in our model which was found significant at  $<0.001$  significance level. The path between innovation to green practices and green practices to environmental performance were both found significant on  $<0.001$  level. But the direct relation between innovation and environmental performance was not found significant in the full model with all the paths corroborating the fact that the magnitude of green practices mediates the relation between innovation activities and organisation's environmental performance providing support for the H8. Similar process was adopted for lean and environmental relation and all three individual paths were found significant at  $<0.001$  level but the direct relation between lean and environmental performance was not found significant in the full model (figure 2). Therefore, according to Barron and Kenny's (1986) theory we can conclude that green practices mediates the relation between lean manufacturing and environmental performance providing support for H3. Since both the direct relation become insignificant, we can infer a full mediation effect (Sarstedt et al. 2014; Hair et al. 2014).

#### **4.1- Discussion and conclusion**

The PLS calculation shows that green practices mediate the relation between innovation and environmental performance as the direct path between innovation and environmental performance was not found significant. This provides a new insight into the relations between these variables. As innovative practices of bringing new products or process, finding new way of using existing products and services actually affects the dependent variable environmental performances. Moreover, green practices were also found mediating the relation between lean manufacturing and environmental performance. This shows that the magnitude of green practices like EMS, LCA, design for environment mediates the relation between lean practices like JIT, TPM, VSM and the environmental performance in reducing carbon emission, other resources usages and pollution prevention and controlling techniques. This is also consistent with the previous findings by Hajmohammad et al. (2013). Her analysis on the Canadian manufacturing companies suggested a mediating effect of green practices in the relation between lean manufacturing and environmental performance. Our analysis also showed that green practices are the main driver of attaining better environmental performance as the direct relation between lean, innovation and environmental performance. The investment made in implementing green practices is related to better environmental performance. This finding supports the findings of previous research (Zhu and Sarkis 2004; Sarkis et al. 2011). This research investigated the integration of three distinct (often conflicting) supply chain paradigms lean green and innovation and measures their impact on environmental performance. The analysis of the model showed a good fit with the data (SRMR less than 0.80). The coefficient of determination R squared values showed a good predictive accuracy of the model. We found that the extent of green practices sequentially mediates the relation between independent variables lean and innovation on the dependent variable environmental performances. Individually the relation between lean and innovation, lean and green, green and environmental performances, innovation and green practices were found significant. The hypothesis regarding the direct relation between lean-environmental performances and innovation-environmental performance were not supported corroborating the fact that the extent of lean and innovation practices does not directly improve the carbon mission,

pollution preventive and controlling performances, rather they affect the performance through the extent of green practices.

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# **IMPACT OF GREEN SERVICE ON CUSTOMER SATISFACTION AND LOYALTY IN RETAIL SECTOR**

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## **Abstract**

### **Purpose of this paper:**

The competitive advantage of green services has become increasingly noticeable. Companies are competing nowadays on service basis, not on products basis. The retailers as a significant entity of supply chain are beginning to explore approaches for green activities that adequately addressing current environmental concerns, and creating a value for customers, investors, and the environment. Therefore, this research seeks to investigate the impact of green services on the customer satisfaction and loyalty in the retail sector and recommend actions to help retailers to improve green services practices that impact on the customer satisfaction.

### **Design/methodology/approach:**

This research is a mix between exploratory, descriptive and explanatory research. The researchers are used semi structured interviews and survey as data collection methods. The survey is reviewed by two scholars and an expert in field of green practices in order to ensure the validity of the survey for the collecting data. The researchers are used SPSS software to analysis data and conduct reliability test by evaluating Cronbach's Alpha. The researchers conducted correlation analysis are used to test study hypotheses by finding the relationships between the independent and the dependent variable(s). In addition to, ANOVA is used test to examine the difference between different groups within the same variable.

### **Findings:**

The Key Findings of Results show there is a significant impact of Green Service on Customer Satisfaction and Customer Loyalty.

### **Value:**

The value of this research is to fill the gap in previous and relevant practitioners' studies that recommend to conduct further studies focusing on green services instead of green product and its impact on customer's satisfaction and loyalty.

### **Research limitations/implications (if applicable):**

This research focused on the green services in Alexandria city, so that further studies can focus on other services in other countries and compare with this study. More studies are needed to ascertain the relation between green service environments and consumer satisfaction, customer loyalty and ultimately profit margins and sales revenues.

### **Practical implications (if applicable):**

This research is a useful guidance for the application green services practices and provide the retailers with corrective actions such as raise the awareness of green service practices

for the customers, reducing air pollution and fuel consumption and installation of environmental education kiosks.

## INTRODUCTION

Nowadays, 'Green' is the slogan in business world. Global warming, the scarcity of natural resources and increasing customer awareness of green products enforced governments and international bodies to play a more serious role towards the sustainability of the environment (El barky and El Zarka, 2015). According to Walker et al. (2008), GSCM is *"Integrating environmental thinking into supply-chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life."*

Retailing is an important entity in supply chain. It is the last point in a channel of distribution. It refers to the selling of goods or services from companies to individual end-consumers. Retailers often act as the communication between manufacturers, wholesalers, and the consumer (Davidson, 2000). Retailing includes the business activities involved in selling goods and delivering services to consumers. In addition, retailers seek to establish and maintain a long-term relation with customers, rather than acting as if each sales transaction is a completely new encounter such as: concentrating on the total retail experience, monitoring satisfaction, and staying in touch with customers. In addition, the customer service expectations are high at a time when more retailers offer self-service and automated systems (Dobson, 2002). The competitive advantage of services has become increasingly noticeable. Companies are competing nowadays on service basis, not on products basis (Kandampully, 2002). A successful Retail includes store atmospherics, customer service, attractive merchandise selections at value prices, efficient supply chain management, and advanced technology (Kraft et al., 2010). For the retail industry trends, the retailers have responded to the consumer trends by reducing their costs to increase the value provided, targeting the needs of specific market segments and beginning to offer a personalized shopping experience. On the other side, they also are beginning to explore approaches for green activities to include all processes, products, services, and manufacturing activities adequately addressing current environmental concerns, and creating a value for customers, investors, and the environment (Ming et al, 2015; Anderson, 2006; Rennie, 2008).

Emmett and Sood (2010) assumed that the environmentally-friendly features of the retailer to cope with green supply chain practices and satisfy the customer's needs include:

- Using skylights for natural lighting and high efficiency lighting.
- LED lighting and lower energy consumption.
- Using sensor for water usage.
- Native plant species that minimize irrigation requirements.
- Use of low toxicity materials to improve air quality and safety of staff and customer.
- Installation of environmental education kiosks to educate people.
- Reduced air pollution and fuel consumption.
- Recycling of solid waste.

According to the Bureau of Labor Statistics (BLS), the definition of green goods and services includes activities in businesses that produce goods or provide services that benefit the environment or conserve natural resources. Those green goods and services fall into one or more of the following five categories:

- Energy from renewable sources.
- Energy efficiency.
- Pollution reduction and removal, greenhouse gas reduction, and recycling and reuse.
- Natural resources conservation.
- Environmental compliance, education and training, and public awareness.

Excellent services quality that are provided by retailers and wholesalers could gain greater acceptance from customers as well as leading to high level of satisfaction and loyalty (Huang (2008); Liu et al.(2005); Kim et al., 2009). Many authors (chang and fong 2010;



Ambec and Lanoie 2008; Trung and Kumar, 2005; Rao, 2002; Mutingi et al, 2014) suggested that green product and green service may be a 'solution', helping organizations to improve customer satisfaction, competitive advantage and environmental performance.

Few studies done by (Chen, 2010; Noci and Verganti, 1999) showed that not only can environmental image satisfy the customer's environmental desires and green needs, but it can also increase their sales and enhance their competitive advantage and corporate image in the global market. Chang and Fong (2010) investigated the impact of green products to customer satisfaction and loyalty. The authors are recommended for conduct further studies focusing on green services instead of green product and its impact on customer's satisfaction and loyalty. Therefore, this research seeks to fill this gap through examining the impact of green service on the customer satisfaction and loyalty in the retail sector through:

- Assessing the impact of Green services on customer satisfaction in the retailing sector.
- Assessing the impact of Green services on customer loyalty in the retailing sector.
- Determining the impact of Customer satisfaction on customer loyalty.
- Recommend actions to help retailers to improve green services practices that impact on the customer satisfaction.

## **REVIEWING THE LITERATURE ON GREEN SERVICES AND CUSTOMER SATISFACTION**

The researchers focused on the literature that addressed the green practices in retail sector and green services. The researchers reviewed 100 articles that published in from the year 2000 to 2015 in international scientific journals available in electronic databases such as Elsevier's Science Direct, Emerald Publishers, Springer, IEEE, and Google Scholar. The following is a review of the previous literature that reflects the positive impact of green services and practices on customer satisfaction and loyalty.

In 2008, Chen conducted study to investigate the relation between green innovation and green image. The results show that the green core competences of companies were positively linked to their green images and green innovation performance. Green innovation performance had partial mediation effects between green core competences and green images of firms. As well, Zhu et al. (2008) declared Chinese manufacturing companies has realized the importance of green supply chain management due to potential regulatory pressure in China as well as pending marketing pressure from Europe when they export products.

Chang and Fong (2010) investigated Green product quality and its effect on customer satisfaction and loyalty. The results of their study showed that Green product quality has a positive impact with green customer satisfaction and green customer loyalty. Also, the Green corporate image has a positive impact with green customer satisfaction and green customer loyalty, and the Green customer satisfaction is positively associated with green customer loyalty. In the same year, Robinot and Giannelloni (2010) found that the environmental attributes were evaluated as "basic", which means they were seen as an important part of the service offer, rather than as differentiating standards.

Eltayeb et al (2011), analysed the relationship between green supply chain practices and performance outcomes and identified the key initiatives (eco-design) that have positive effect on the four types of outcomes (environmental, economic, cost reductions, and intangible outcomes).

In 2011, Chiou et al. studying about green innovation and competitive advantage in Taiwan the finding showed that companies have started to implement actions towards greening their suppliers and developing greener products and manufacturing process. Furthermore, greening the suppliers leads to green innovation and competitive advantage. El tayeb et al. (2011) showed that: Eco-design has an important positive effect on the four types of outcomes (Environment al, economic, operational, and intangible). Shamah (2012) conducted study that address innovation within green service supply chains for a value creation. The results of study showed that the key factor for successful value creation

for green service supply chain is innovation; sharing knowledge; trust and joint productivity. Also, there is a direct and significant linear relation between reducing operational cost and achieving customer satisfaction. In the same year, Slevitch et al. (2013) confirmed that Green attributes for products and services impact on customer satisfaction similarly to facilitating attributes but differently from the core type of attributes in the context of lodging industry. In 2013, Chang and Chen studied the impact of green perceived quality on green satisfaction and green trust. The results showed that green perceived quality would positively impact on green satisfaction and green trust. The authors investing resources in the increase of green perceived quality and the decrease of green perceived risk are useful to enhance green satisfaction and green trust.

Several studies have found the positive relationship between customer satisfactions and customer loyalty (Anderson et al. (1994); Cronin and Taylor, 1993; Fornell, 1992; Oliva et al., 1992; Anderson and Sullivan, 1994; Bloemer and Kasper, 1993). On the other hand, some researchers believed that Satisfaction does not guarantee loyalty (Mittal and Lassar, 1998).

Few studies done by (Chen, 2010; Noci and Verganti, 1999) showed that not only can environmental image satisfy the customer's environmental desires and green needs, but it can also increase their sales and enhance their competitive advantage and corporate image in the global market. Chang and Fong (2010) investigated the impact of green products to customer satisfaction and loyalty. The authors recommended the researchers to conduct further studies focusing on green services instead of green product and its impact on customer's satisfaction and loyalty.

## RESEARCH PROBLEM

According to the lack of studies that concern with the relationship between green service application and customer satisfaction and loyalty, the research problem summarized in the following question that need answer:

1. Does the green service has impact on the customer satisfaction and loyalty?

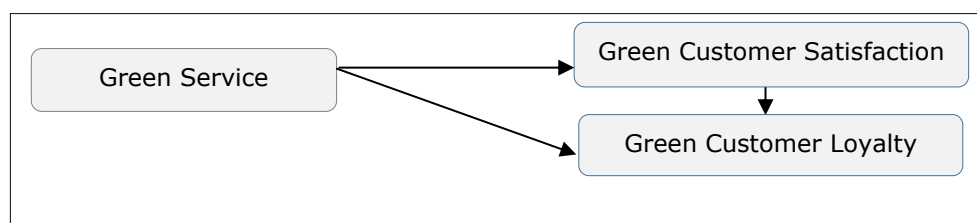
## RESEARCH OBJECTIVES AND HYPOTHESES

This study proposes a rare and novel constructs respectively – green customer satisfaction and green customer loyalty, and develops a research framework to explore the relationships among green services, green customer satisfaction, and green customer loyalty. The research hypotheses have proposed based on the findings of the previous studies as follows. This research investigates the relationships among green service as independent variable, customer satisfaction and customer loyalty as dependent variables as shown in figure 1.1. The research's hypotheses are proposed based on the studies done by (Chang and Fong (2010); Chen, (2001); Noci and Verganti, (1999) as follows:

H 1: Green service is positive related with customer satisfaction.

H 2: Green service is positive related with customer loyalty.

H 3: Customer satisfaction is positive related with customer loyalty.



**Figure 1. Research Model**

## RESEARCH METHODOLOGY

This research is a mix between exploratory, descriptive and explanatory research. It explores and describe the green dimensions of services in the literature review and real life context. Also, it explains the relationships between green service implementation and

customer satisfaction and loyalty. The researchers are used semi structured interviews and survey as data collection methods. Semi-structured interviews are conduct with different retail managers in order to identify the appropriate case study "City Centre" for the research that apply green practices. Then, the survey is design based on interviews findings and literature review to include two main parts. Part 1 includes three sections that include thirty-one questions which tests the relation between research variables using a five-point Likert scale. Part 2 includes 6 demographic questions about the respondent`s personal information to clarify results and recommend solutions and corrective action based on each segment of customers.

The survey is reviewed by 2 scholars and an expert in field of green practices in order to ensure the validity of the survey for the collecting data. The researchers are used SPSS software to analysis data and conduct reliability test by evaluating Cronbach's Alpha. The researchers conducted correlation analysis are used to test study hypotheses by finding the relationships between the independent and the dependent variable(s). In addition to, ANOVA is used test to examine the difference between different groups within the same variable. If a certain variable contains only two groups, then the T-Test is used.

## RESULTS AND DISCUSSION

Descriptive statistics are used to describe the basic features of the data in the research. These statistics provide simple summaries about the sample of 400 customers and its measures. Frequency is considered one of the tools of descriptive statistics. Based on the descriptive analysis, the data revealed that the sample mixed equally between women and men that belong to the youth 58% and well educated customer 39% with income more than 2000 L.E 44%.

Regarding validating, It was found that all research variables have AVE greater than 50% and all factor loadings are greater than 0.40. Thus have adequate validity. Regarding the Reliability, the results show all alpha values exceeds 0.7, which is an acceptable level for the reliability of the variables.

Correlation matrix is a matrix giving the correlations between all pairs of data sets, by calculating the Spearman's Correlation Coefficient between variables under study. The correlation coefficient value ranges between 0.00 (no correlation) and  $\pm 1.00$  (perfect correlation) (Foster et al., 2004). A correlation matrix between Green Service Quality, Customer Satisfaction and Customer Loyalty is illustrated in table 1, where the value of Spearman's correlation is calculated.

**Table 5: Correlation Matrix between Green Service Quality & Customer Satisfaction**

		Green Services	Customer Satisfaction	Customer Loyalty
<b>Green Services</b>	Correlation Coefficient	1.000		
	Sig. (2-tailed)	.		
	N	400		
<b>Customer Satisfaction</b>	Correlation Coefficient	.191**	1.000	
	Sig. (2-tailed)	.000	.	
	N	400	400	
<b>Customer Loyalty</b>	Correlation Coefficient	.166**	.498**	1.000
	Sig. (2-tailed)	.001	.000	.
	N	400	400	400

Results show that the correlation coefficient is 0.191 with P-value of 0.000. This means that there is a positive significant weak relationship between the variables; Green Service and Customer Satisfaction at 0.01 significance level. This means the acceptance of the first hypothesis, which is Green service is positive related with Green customer satisfaction. The results are confirmed with the previous studies of (Chan and Fong 2010; Shamah 2012; Abdullah et al., 2000; Chang and Tu, 2005; Martenson, 2007; Schellhase et al). Also, it is shown that the correlation coefficient between Green Services and

Customer Loyalty is 0.166 with P-value of 0.001. This means that there is a positive significant weak relationship between the variables; Green service and Customer Loyalty at 0.01 significance level. This means the acceptance of the Second hypothesis, which is Green service is positive related with green customer loyalty. The results are confirmed with the previous studies of (Chan and Fong 2010; Shamah 2012; Abdullah et al., 2000; Chang and Tu, 2005; Martenson, 2007; Schellhase et al.).

Finally, it is shown that the correlation coefficient between Customer Satisfaction and Customer Loyalty is 0.498 with P-value of 0.000. This means that there is a positive significant moderate relationship between the variables; Green Customer Satisfaction and Green Customer Loyalty at 0.01 significance level. This means the acceptance of the third hypothesis, which is Green Customer satisfaction is positive related with green customer loyalty. The results are confirmed with the previous studies of (Chan and Fong, 2010; Hellier et al., 2003; Butcher et al., 2002; Gountas and Gountas, 2007; Zboja and Voorhees, 2006; Fornell et al., 2006; Oliver, 1999).

ANOVA test is used to examine the difference between different groups within the same variables. If a certain variable contains only two groups, then the T-Test is used, while in case the variable contains more than 2 groups, then Analysis of Variance ANOVA will best fit.

Using T-Test, the results show an insignificant difference between means of different gender groups for both Green service and Customer Loyalty, while there is a significant difference in customer Loyalty according to gender. The results revealed that Females Customer Loyalty is greater than Males Customer Loyalty, as average customer loyalty of females equals 3.99, while that of males equals 3.68.

ANOVA test results that are used to compare the groups mean for Green Service, Loyalty and Satisfaction with respect to Age groups. Regarding Age, the results show Green Service and Customer Loyalty significantly differ with different Age groups. Regarding Green Service, it could be claimed that the customers greater than 40 years old consider Green Services as most import with an average of 4.54, then customers between 30 and 40 years old, with an average value of 4.45. This means that the elder people are concerning with the importance of green practices in service delivery. The third rank is for customers less than 20 years old with an average value of 4.42, while the least group is customers between 20 and 30 years old, as their average value of Green Service importance is 4.27. This mean that youth slightly concern with the green practices and could concern more with the quality and price of service. Consequently, Customer Loyalty, it could be claimed that the customers greater than 40 years old have the highest loyalty with an average of 4.06, then customers between 30 and 40 years old, with an average value of 3.95. The third rank is for customers between 20 and 30 years old with an average value of 3.81, while the least group is customers less than 20 years old, as their average loyalty is 3.51.

Regarding to educational level and income level, results show that none of the research variables is significantly changing with different groups of Education.

## **CONCLUSION**

The main contribution of this research was to develop a research framework to explore the relationships between green services, customer satisfaction, and customer loyalty. Therefore, this study successfully filled the research gap about green issues and their relationship with customer satisfaction and customer loyalty. The Key Findings of Results show there is a significant impact of Green Service on Customer Satisfaction and Customer Loyalty. In order to develop a robust relationships with customer the retailers shall take into consideration the application green services practices and take the following corrective actions:

- Raise the awareness of green service practices and their benefits and impacts on the society for the customers, in particular male and youth customers

- Involves females and elder customers in awareness session and events that related to green practices to keep and raise their satisfaction and transfer their concern to other customers.
- Reducing air pollution and fuel consumption, increasing interior spaces for shopping, increasing green space and attention to developing guidance signs inside Carrefour for easy knowing places.
- Installation of environmental education kiosks in the store to educate customer in sustainability practices.
- Establishing onsite recovery system (for instance: recycling machines) for customer and staff to gain competitive advantage and provide the customers to incentives in terms of money, point..etc.

This study focused on the green services in Alexandria city, so that further studies can focus on other services in other countries and compare with this study. More studies are needed to ascertain the relation between green service environments and consumer satisfaction, customer loyalty and ultimately profit margins and sales revenues.

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## **Session 11: Supply Chain Performance Assessment**

# **IMPROVING SUPPLY CHAIN PRACTICES IN A LUXURY FASHION COMPANY IN THE MIDDLE EAST AND THE NEAR EAST**

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## **ABSTRACT**

Supply chain practices have a high impact on a company's ability to compete in the market as well as in its profitability. The positioning of its inventory and its supply chain practices determine the ability to react to changes in demand, as well as the ability to fulfil customer's requests. Cultural characteristics as well as long term practices can influence both its efficiency and effectiveness. The purpose of this paper is to analyse supply chain practices and its impact in supply chain performance in the luxury fashion industry, which represents a market not widely studied in the supply chain management literature. Particularly, this paper aims at exploring a supply chain of luxury fashion products operating in the Middle East and the Near East while assessing the efficiency and effectiveness gains from supply chain adjustments. Data was collected using direct observation and semi-structured interviews at the office of the company for the Middle East and the Near East. Findings show that the main constraint to improve customer service is lack of visibility and long lead times, which lead retailers to frequent shortage gaming practices. Analysis and managerial recommendations lead to position decoupling points, reduce lead times and simultaneously reduce customer complaints and the bullwhip effect while improving visibility and forecasting practices.

**Keywords:** supply chain management; supply chain strategies; decoupling points; bullwhip effect; luxury fashion products

## **INTRODUCTION**

There is wide span of research in the area of supply chain management. It is an area in which companies can gain competitive edge. Defining the best companies to work with in the supply chain and the best management strategies is paramount to succeed in the market. Much has been recommended in terms of supply chain strategies (see, for instance, Fisher (1997), Christopher and Towill (2000) or Lee (2002)), or how to position inventories (see, for instance, Naylor et al. (1999)). Still, the luxury market, eventually due to its high margins, is still in its infancy in terms of research (see, for instance, Caniato et al. (2011) or Castelli and Sianesi (2015)). Most research has been based on the manufacturing perspective, and there is still lack of research on how the products reach the selling points, assuring availability without promoting excessive inventory, mainly in short life cycle products (Caniato et al., 2013). Also, despite the current adverse economic context, luxury goods have been experiencing an increasing demand, which makes it relevant to further explore the best management strategies in this sector (Brun et al., 2008).

Companies selling luxury products are often associated with high margins. Product availability in this market is a key factor as these products have high stock out costs (Lee, 2002). Under these conditions, and taking into account the high demand uncertainty of this market, it would then be expected that supply chains that make



these products available would be managed using responsive approaches, with high flexibility and service levels. Still, this is not always the case and customer satisfaction might not be at the desired level.

Under this context, this paper aims at reducing the gap in supply chain management literature and discussing real challenges faced by supply chains that deal with luxury products. As so the objective of this research is twofold. On one hand it aims at providing research in the context of luxury products thus contributing to fill the gap in literature. On the other hand, it aims at discussing the real challenges faced by a luxury product supply chain and the management decisions adopted to manage flows, and provide input to how it should be adjusted so that market challenges are met.

A case study is used to provide example and clarification of the challenges faced by these supply chains. Managerial recommendations are provided to improve both the effectiveness and efficiency levels of the supply chain.

## **LITERATURE REVIEW**

### ***Supply chain management***

Competition is no longer based on company versus company, but rather on supply chain versus supply chain (Christopher, 2016). The ability of a company to succeed in the market depends on the companies it works with to lead products to market and assure customer service.

Literature provides a wide range of approaches on how to define the best supply chain strategies and practices for each specific situation. Fisher's (1997) provided the baseline approach for this discussion by establishing the difference between functional and innovative products, recommending more efficient supply chain approaches for the former and more responsive ones for the latter. Other authors added new features to this approach, such as product complexity and uniqueness (Lamming et al., 2000), supply uncertainty (Lee, 2002), market critical success factors (Christopher and Towill, 2002), product life cycle, delivery lead time, volume, variety and variability (Childerhouse et al., 2002), among others.

Still, independently on the best supply chain strategy, in order to be able to manage and run their strategy in an effective manner, the entities in the supply chain need to be linked and visibility turns to be a key requirement throughout the chain. Lack of connectivity between the different levels of the supply chain limits efficiency and the ability to compete in the market as it promotes the bullwhip effect (Lee, 1997). According to the same author, the bullwhip effect not only leads to poorer customer service and longer lead times, but also to increased costs and loss of sales. Mainly for short life cycle products, this can lead to obsolete inventory by the end of the selling period. Fighting this effect requires increased visibility and shorter lead times (Lee, 1997), among others.

Nonetheless, lead time analysis cannot be restricted to the period from receiving the order from the customer to the moment the product is made available for that customer (time-to-serve). Christopher and Peck (2003) consider not only this critical lead time, but also the time required to recognise an opportunity in the market and translate it into specific product characteristics (time-to-market) and the time required to adjust the output of a business to meet changes in demand (time-to-react). Time-to-serve is usually focussed on the manufacturing perspective (Christopher et al., 2004), but the downstream part of the supply chain should also be considered as even if the product exists in the pipeline, it has to be moved to the correct place to create availability without generating excess inventory (this issue is specially challenging in short life cycle products).

Furthermore, the ability to react to changes in demand and to serve customers, especially in volatile markets, is also highly dependent on the positioning of the inventory in the supply chain (Mason-Jones and Towill, 1999; Naylor et al., 1999). This inventory will allow leveraging the supply chain strategies (Christopher, 2016), but if poorly managed can lead to increased costs and poor customer service. This is particularly critical in high volatile markets.

### ***Supply chain management in the fashion industry***

Fashion markets have specific characteristics (Christopher et al., 2004) that place an additional effort in managing the supply chain. The products' short life cycles, the high volatility, the high impulse purchasing and the high competition forces new products to be often introduced in the market and their availability to be assured. The tendency to resort to off-shore sourcing of products and materials adds to the complexity of the logistics of these supply chains (Christopher et al., 2004).

Responsive solutions are thus suggested to satisfy challenges in the downstream part of the pipeline (see, for instance, the recent study by Chan et al. (2017)). In order to do so, it is required that i) the organization's activities are aligned with the market, meaning that demand and supply should be synchronised, ii) there is a good reading and visibility over demand, iii) the supply chain architecture is configured to serve demand, meaning that it is able to quickly share information and also allow a fast response to changes in demand in both volume and variety iv) timely and accurate information is a reality throughout the supply system, and v) the elements of the supply chain are strongly connected through partnerships and alliances so that changes in the market can be better dealt with (Lowson, 2002).

### ***Supply chain management in the luxury fashion industry***

The luxury fashion, eventually for its specificity, has not been widely focussed in terms of supply chain research. Nonetheless, it is recognised that the ability to provide value to customers in the luxury fashion is more and more a consequence of the competences of the entire supply chain and not on branding alone (Castelli and Sianesi, 2015). The specificity of this industry (with the tendency to produce short life-cycle products) does not allow wide direct application of the generic recommendations for supply chain management (Christopher et al., 2004; Caniato et al., 2011). Literature refers to the especial need to adjust supply chain strategies in the luxury fashion industry as a key success factor of the industry (Castelli and Sianesi, 2015). Specific combinations of critical success factors will require the most adjusted supply chain choices.

Within this setting, the proposed paper aims at filling this gap in the literature by developing research applied to the luxury fashion industry, as well as by exploring which supply chain strategies and practices are the most adequate to this particular setting.

## **STRUCTURE OF SUPPLY OF COMPANY X**

### ***Company X***

Company X (for confidentiality reasons the name of the company will not be disclosed) is about 180 years old and is very well known and recognised for its luxury items. The company has a wide range of products, from clothes to perfumes, accessories and jewellery.

The company considers perfumes as a different type of luxury fashion product and a fast moving one, and so a specific type of management was adopted for perfumes both in terms of the internal structure of the company, as well as in terms of its supply chain. The company has two main divisions in the perfumes area: one dedicated to bathroom products (soaps, gels, lotions) and a second one devoted to home products (mostly air conditioners and candles).

The company operates under a geographical division approach. This research focusses specifically on the Middle East and the Near East (MENE) region, which also serves some African countries, such as South Africa or Angola. The headquarters for this region are located in Dubai. Within this region, three market segments can be identified: local markets (covers the brand stores and also independent perfume stores and chains); travel retail (which covers airport stores and airplanes); and hotels (amenities). Local markets are managed by a group of account managers, each in

charge of a specific group of accounts; the travel retail is managed by a single account manager; and the hotel channel is also managed by a single account manager.

### **The Supply Chain for the Perfumes**

The overall supply chain can be traced back to France, where production is held. The factory holds both raw-material and finished product inventory. There is a secondary location for finished products for MENE, operated by a 3PL, and located in Dubai.

The local markets are supplied by the warehouse at MENE. Deliveries will depend on the market segment:

- i. Local markets segment: deliveries can be made to the warehouses of retail chains or directly to retail stores; orders are received by the Company sellers;
- ii. Hotel segment: also supplied by the warehouse at MENE, through the local distributors, but there are exceptional customers that are supplied directly from the warehouse in France;
- iii. Travel retail segment: also supplied by the warehouse at MENE; in this case the company sellers are not used, and it is the account manager from MENE who plays the seller role.

Figure 1 shows the physical structure of the supply chain along with its main physical and informational flows.

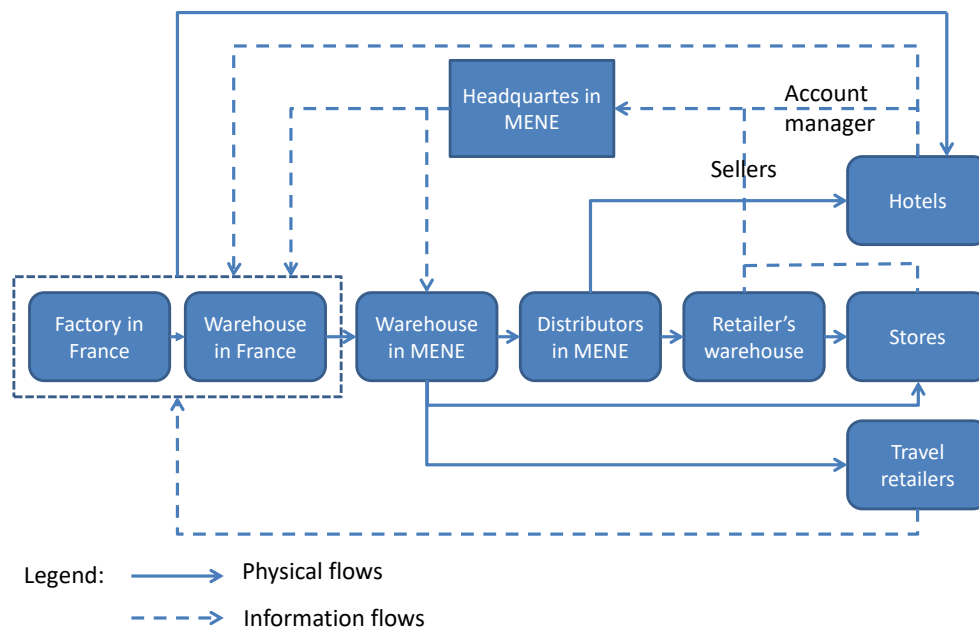


Figure 1 – Physical and informational flows in the supply chain of Company X

The Company produces using a make-to-stock approach. Volume of production is based on forecasts developed jointly with the local branches (that collect provisional data from the local agents). Once the production is finished, final products are stocked in one of the two warehouses – these warehouses represent the material decoupling points of this supply chain. Regarding real demand, it is only known at the stores. From these points upstream there is no information about real demand - only the orders placed by each element in the supply chain to its suppliers is known from this point onwards, and no information on the reasons for the demanded volumes is provided. The more upstream the orders are placed, the more uncertainty exists. Orders are placed directly to its own suppliers by each supply node based on market sensitivity, inventory level, budget, target sales, among others factors. For this reason, the stores represent the information decoupling point of Company X's supply chain.

All physical movements are made by truck, except urgent ones that can use airfreight.

### ***The Supply Process for the Perfumes***

The company makes a wide range of products available – it includes basic products, novelties, promotional and limited editions. These products include both saleable items (the ones to be purchased by the final customer) and point of sales material (support items, such as testers and samples). These different products differ in terms of demand uncertainty, lifecycle, variety and profit margins. Particularly, basic products represent the ones with lower uncertainty associated, longer lifecycles, smaller variety and lower profit margins, whereas promotional and limited editions are characterized by higher demand uncertainty, shorter lifecycles, higher variety and higher profit margins.

Independent from the type of product, the company operates under a forecast-driven process, with production being fully based on speculation and demand anticipation. Nevertheless, while the headquarters in France uses historical data to forecast basic products' demand, the remaining products are forecasted in a different way – these are forecasted using previous sales data of similar items previously launched, and these forecasts are then adjusted by account managers based on their market knowledge (no information is required to support the forecasted volumes). Accordingly, the unpredictability of these new launches may result in shortages or excess of inventory, representing one of the reasons for the bullwhip effect in the Company's supply chain. In addition, the uncertainty underlying non-basic products often leads to not served customers (due to shortages), which results in some trust issues with the final customers. If forecast inaccuracy is large and the volume of urgent orders is enough, there is the possibility to undertake urgent production runs. These are not often situations. If demand is higher than expected but not enough to justify an urgent production run, unused testers have already been locally transformed into selling products. These situations emerge due to the efficiency goals set to the production area.

Another reason for the bullwhip effect is the lack of an integrated information system to support all the processes of the Company. In fact, so as to share information throughout the supply chain, as well as to manage and control the flows of products, several tools are used by the company, with different departments having its own information tools. This disintegration makes it difficult to ensure a smooth flow of information throughout the company.

An additional challenge that need to be dealt with by the Company is related with the supply, since certain visuals, marketing materials and packaging used in Europe are not accepted in ME, given that they are not appropriate to the rules and culture of this society. This thus results in a higher uncertainty in the supply side (as it increased the variety of support materials to be produced), and results in a limited number of available suppliers (as the number of suppliers producing the specific materials is limited as a consequence of limited production volume).

The changing regulation in the regions where the Company does business represents another challenge for the Company. Whenever new regulations are in place in a given region, the Company needs to quickly react to those changes so as to avoid penalties or, in the worst case, blocked shipments.

Based on the conceptual framework and the current positioning of Company X, the research question pursued in this research is:

- *Which issues should be addressed by Company X to improve its ability to serve variability in the Middle East and Near East market?*

### **METHODOLOGY AND METHODS**

Due to the exploratory nature of this research, a case study approach was used (Voss et al., 2002; Yin, 2009). This approach allows exploring unknown phenomena in their natural setting to generate meaningful understanding (Voss et al., 2002). For confidentiality reasons the name of the company is not disclosed. Data was collected from different levels of the supply chain, starting at the central inventory point in the

country of origin down to the retail points. Data collection was based on direct observation and eight semi-structured interviews at different levels of the supply chain in the Middle East and Near East part of the structure. This data was compared with secondary data to assure data triangulation (Eisenhardt, 1989).

An initial description of the supply chain structure was defined. Based on the interviews and direct observations the relationship between the different supply chain links was identified. Managerial practices were identified using the semi-structures interviews, and these were then confirmed with data from direct observation and secondary data from the company.

## **FINDINGS AND DISCUSSION**

From the description of the case it is clear that the flows of information are not sufficient and not all the information available in the system downstream is shared with the upstream links of the supply chain. This situation leads to forecast errors and difficulty in matching supply with demand. There is not a clear and common strategy that is followed across the Company – depending on the type of product different strategic moves arise as the most adequate ones.

A more efficient supply chain approach is in place for basic long lifecycle products, whereas a more responsive strategy should be in place for novelties and short lifecycle products. According to Castelli and Sianesi's (2015) stratification of critical success factors, traceability and market orientation should be the supply chain objectives pursued by companies with this profile, leading to the maintenance of its brand reputation and exclusivity critical success factors.

The positioning of material decoupling points is based on transportation efficiency. As demand forecast is complex and there is lack of visibility, the Company is forced to use urgent production runs and transportation to serve customers. As there is lack of flexibility in production runs (due to minimum batch sizes), it is possible to miss market opportunities when they emerge.

Currently there is a material decoupling point at the warehouse in France and another one can be found for this market at the regional warehouse (in Dubai). Also, practices upstream to the local material decoupling point should be mainly based on an efficiency strategy (with production being planned based on forecasts and while taking advantage of economies of scale), whereas downstream the material decoupling point the strategy should be based on responsiveness. The lack of visibility and supply chain flexibility forces products to be moved ahead of time to create speculative inventory (the consequences of such option are even more severe taking into account the wide range of products and demand variability of each one of them). This leads to build bullwhip effect, which fights the market orientation objective for the supply chain.

Although its current focus on efficiency instead of on responsiveness from the material decoupling point forward, the Company is still able to keep customer satisfaction. This is mostly based on the local culture of finding ad-hoc solutions to overcome bottlenecks and shortages. Adjustment to the supply system, both in terms of structure, information system and practices would avoid these last minute solutions.

## **MANAGERIAL RECOMMENDATIONS**

Despite being a successful company in the luxury fashion industry, particularly in the perfumes area, there are several adjustments and improvements in the way Company X should manage its supply chain.

Since one of the biggest challenges faced by the Company is the bullwhip effect, there are several recommendations that will allow reducing this effect. First, there is need to improve the supply chain visibility by developing stronger alliances with local companies/retailers. This will lead to improved customer service and better supply chain response. Also, so as to build a trust relationship with its customers, there is need to start working in close collaboration with its customers. For instance, adopting a vendor managed inventory partnership would give the company the opportunity to control and manage the inventory at their customers using data on real sales at the

point of sale. This would avoid the need to rely on overestimated forecasts to plan its production runs, which represents the current practice for many non-basic products. Secondly, an integrated information system should also be adopted by the company. This would allow a smoother flow and sharing of information on the inventory levels, real demand and forecast sales through the chain. Simultaneously, it would give the Company the chance to perceive the level of activity of the business at its various regional divisions. As products are sold based on availability (which leads to customer satisfaction) and stock outs lead to immediate loss of sales, information sharing is essential to assure availability without excess inventory.

In line with this second managerial recommendation, inventory kept at the regional warehouse in Dubai (main material decoupling point for the region) should be able to serve all regional customers and be moved to customers based on information from real demand. The recommended information system would allow real sales and inventory visibility. Specifically at MENE, visibility by the headquarters in Dubai would improve inventory management among the different channels and locations to be served. Consequently this information system could reduce the bullwhip effect by reducing demand uncertainty and speculative inventory moves.

Thirdly, since there is a certain level of uncertainty in the supply side, some adjustments may also need to be done at this level. Particularly, since the supply sources with which the company work with are limited, long-term contracts with a lower level of flexibility should be established with these suppliers. The establishment of this type of contracts will diminish the risk of having stock out of raw materials, and consequently, of having shortages of finished products. Also, the establishment of contracts that ensure the credibility of the information shared between partners should also be considered. Examples of such contracts are the capacity reservation or advanced contracts.

## **CONCLUSIONS**

Although a wide body of research exists devoted to the problem of analysing the most suited strategies and practices to manage supply chains in general, a lack of research exists in the luxury fashion industry in particular. Within this setting, this paper aims at filling this gap in the literature by i) developing research in the particular context of luxury products and ii) discussing the real challenges faced in this type of industry, while exploring management strategies and practices that can be adopted to ensure an efficient and effective management of supply chains in this particular industry.

As a case study, a company recognized for its luxury items, such as clothes, perfumes, accessories and jewellery, is considered. Since each type of product has its own particular characteristics, the particular case of perfumes was considered for analysis.

As key results, it was found that Company X does not follow a clear supply chain strategy and that it is mostly focused on efficiency while the market aims for product availability. This mismatch between supply chain practices and demand and product profile lead to poor transfer of information through the supply chain and consequent bullwhip effect, to poor location of decoupling points, and to urgent moves to supply demand.

This study thus presents several managerial recommendations that have potential to improve the performance of the company under study. In general, these recommendations play a key role in reducing the bullwhip effect, one of the most relevant challenges faced by the company. Particularly, it is recommended to improve the collaboration with local companies, suppliers and also with its customers through the establishment of partnerships and alliances. The establishment of different types of contracts with suppliers is also proposed, as well as the investment in an integrated IT system. It should be noted that these recommendations are specific for this company, but can also be valid for other companies in the luxury industry facing the same challenges and within the same circumstances.

As further research it is suggested that more company products are added to the research in search for synergies in terms of supply and managerial practices.

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# **AN OPTIMAL ROUTE SELECTION MODEL USING FUZZY LOGIC IN MULTIMODAL FREIGHT TRANSPORT NETWORK**

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## **ABSTRACT**

This paper proposes a route selection model based on the Fuzzy Logic approach in multimodal transport network in order to find the most optimal route among the set of given route alternatives so that transport route planners can make a route selection decision efficiently and effectively. The proposed approach uses the transport data of time, cost and reliability for each alternative route in order to measure the degree of transport route performance. This research also conducted a case study in order to demonstrate applicability of the proposed model in real-world applications.

## **INTRODUCTION**

Global business transactions are escalating at an unprecedented rate aligned with the growth of domestic business transactions through the world. The global logistics costs in 2015 were estimated at USD 8661 billion, and corresponded to 11.7 per cent of the world's gross domestic product in that year (Armstrong, 2016) and international logistic costs depending on its industry type may account for 30%-50% of a company's total production costs (Min, 1991). Over the past decades, international logistics has become decisive to gain competitiveness in the world marketplace and this has forced companies to consider implementation of advanced logistics techniques and utilizing multimodal solutions throughout the global transport operations in order to improve productivity and reduce logistics costs. Multimodal freight transport provides a more efficient, productive and sustainable transport network by gathering many transport modes. Multimodal transport mainly describes a multi-unit transport network with nodes and legs in which transport are conveyed with at least two different transport modes (e.g. rail-road, rail-rail, river-road, sea-road, sea-rail) on the basis of a multimodal transport contract from a place (origin) in one country at which transport units (e.g. semi-trailers, containers) are taken in charge by the multimodal transport providers (MTPs) in transport means (e.g. RoRo vessel, RoLa train, ISU) to a designated place (destination) for delivery in a different country (UN, 1980). Its aim is to provide a seamless door-to-door (or terminal-to-terminal or port-to-port) service. The transport network needs to be designed in a flexible way to meet the changing conditions, and also it is critical decision for MTPs which multimodal freight routes in main-haulage should be offered to the companies (shippers) (Kayikci, 2014). The planning of a multimodal freight route allows to minimize the transport costs and also provides information for shippers to negotiate a more favorable price with MTPs as well as for MTPs to maximize their profitability across all service lines with using appropriate pricing strategy (Barnhart and Ratliff, 1993, Kayikci, 2014). But the planning process of a multimodal freight route is never an easy task because the decision-making process is affected by conflicting objectives of e.g. transport cost, quality of on-time service, and the transport risk, scheduled transport modes and delivery times and transport economies of scale (Chang, 2008); the capacity of transfer terminals may also create problems due to the modals shift of transport modes (Hokey, 1991; Woxenius, 2007).

The purpose of this paper is to develop a route selection model in multimodal freight transport networks for MTPs by using Fuzzy Logic approach encompassing all aforementioned characteristics. The Fuzzy Logic approach is selected as a solution methodology to develop the model in multimodal transport network, which will help



practitioners to react the changing conditions and decide on an optimal route quickly among given alternatives. Although a number of existing researches have already modelled multimodal route selection problems (Chang, 2008, Kengpol, et al. 2012), to the best of our knowledge, there is no approach so far that deals with the route selection problems from the side of multimodal services, moreover Fuzzy Logic has not been offered as a solution methodology to solve the routing problem. The reason behind this decision is that Fuzzy Logic method could be applicable to solve the multimodal routing problems in response to the high changeability rate in weather, contracts and rates in freight transport cases. The Fuzzy Logic theory is used to compare the alternative routes according to multiple objectives to minimize both travel time and cost while keeping the quality of service at a required level and to select an optimal one. Here also scheduling and capacity planning of transport modes are considered for route selection. The proposed model uses the cost, time and reliability data for each determined multimodal service route as input parameters, after pursuing Fuzzy Logic approach, route performance data will be calculated as output parameter. The practitioners might decide on an appropriate route according the performance results. The higher the level of the route performance, the higher the willingness of MTPs to offer this multimodal freight route to shippers. This Fuzzy Logic based model solely considers sea and rail transport in a multimodal transport network, whereas road transport is kept out of the model.

The rest of the paper is organized as follows: First, the using methodology is described, then a case study is applied into the model, finally the paper is ended with findings and conclusion.

## METHODOLOGY

Recently, a dramatically increasing number of researches use Fuzzy Logic approach for implementation in various fields, such as the description of human behavior in social environment, demand forecasting in dynamic market, logistics and supply chain management etc. Fuzzy Logic methodology is well-known and accepted among both academicians and practitioners because of the fact that it is capable of working with both numeric and nonnumeric characters, and producing states in which to make better decisions (Sabeur and Denis, 2007). In this study, the Fuzzy Logic approach is utilized to create a rule-based model in an attempt to find the degree of transport route performance, by taking into account some essential features of routes, which are transport cost, transport time and transport reliability.

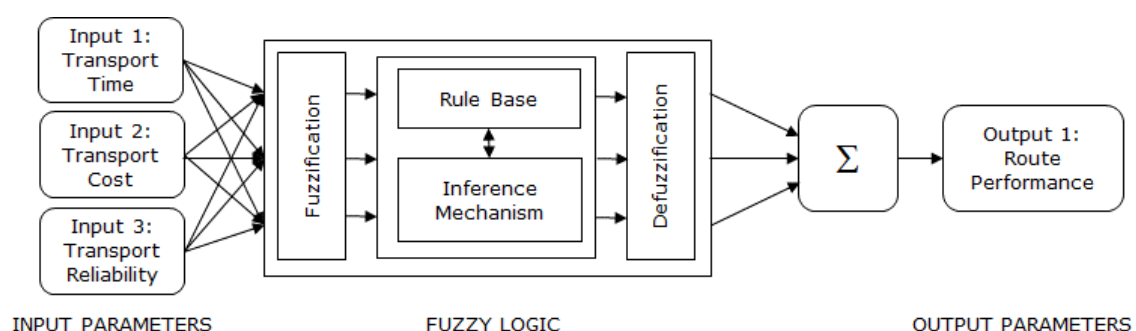


Figure 1: Basic principles of Fuzzy Logic

In the literature, there are numerous Fuzzy models available which are especially classified under three headings: 1) the Mamdani model (also known as Max-Min method), 2) the Takagi-Sugeno model, and 3) Kosko's standard additive model (Sabeur and Denis, 2007). Throughout this current study, the widely known Mamdani model is used, in which the following rules are applied iteratively:

- First of all, *fuzzification* in which all input variables are converted into fuzzy variables is carried out.

- Then, the output determination step is applied to predetermined *fuzzy rules* with input values according to *inference mechanism*.
- The most important step is the output aggregation step in which overall output by gathering all fuzzy rules are completed.
- Lastly, *defuzzification* matches the fuzzy output with the first form.

Figure 1 depicts the basic principles of Fuzzy Logic. In Fuzzy set theory, membership functions  $\mu_a(a)$ ,  $\in [0,1]$  assign to each object a degree of membership ranging on a given scale (Saaty, 1980). Different fuzzy membership functions used by other were considered including a triangular membership function, Gaussian membership function and a trapezoidal membership function (Kayikci and Stix, 2013). These membership functions are associated with the set of linguistic variables, which are Very Low (VL), Low (L), Medium (M), High (H), and Very High (VH), where the combination of Low (L), Medium (M) and High (H) is represented with triangular fuzzy numbers, whereas the trapezoidal fuzzy numbers should be utilized in the case of adding Very Low (VL) and Very High (VH) variables (Becher, 2009). Figure 2 shows the triangular fuzzy numbers,  $\mu_a(a)$  and trapezoidal fuzzy numbers,  $\mu_b(b)$ . We adopted triangular membership functions since they are the most commonly used ones for this study. A triangular fuzzy number  $a$  can be defined by a triplet  $(a1, a2, a3; a1 \leq a2 \leq a3)$ , the membership function  $\mu_a(a)$  is presented in Equation (1):

$$\mu_a(a) = \begin{cases} (a - a1)/(a2 - a1) & a1 \leq a \leq a2 \\ (a - a3)/(a3 - a2) & a2 \leq a \leq a3 \\ 0 & a < a1 \text{ or } a > a3 \\ 1 & a = a2 \end{cases} \quad (1)$$

The Fuzzy Logic approach is based on pre-defined rules that consists of a set of fuzzy "if-then" rules that are collected in forms of linguistic terms by expert's opinions via performing a questionnaire or Delphi-session. The rule is interpreted as an "implication" and consists of the "antecedent" (if part) and "consequent" (then part). The general form of fuzzy rule is given in the following Equation (2):

$$\text{If is } A, \text{ Then is } B \quad (2)$$

where A and B are linguistic terms defined by fuzzy sets on universe of discourse and, respectively.

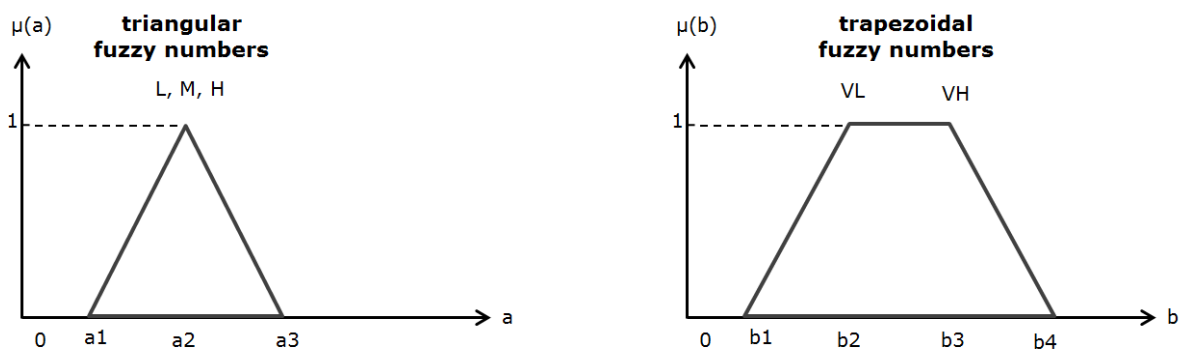


Figure 2: Triangular vs. trapezoidal fuzzy numbers

## CASE STUDY

An Istanbul based international multimodal company offers multimodal services for sea and rail transport and operates frequently from Istanbul to Europa by using various transport means (i.e. RoRo vessel, RoLa train, ISU) and company uses particularly semi-trailers as transport units for the daily shipment. Due to increased demand of multimodal services from Istanbul to Hamburg, multimodal company has decided to offer an

appropriate new service route for its potential customers (shippers) between OD. The new service line should be operated from one loading terminal in Istanbul to another discharging terminal in Hamburg. Loading terminal (origin node) and discharging terminal (destination node) can be a seaport terminal or a railway inland terminal. Between OD, there might be several transfer terminals (multimodal hubs) for modal shifts, where transport modes can be changed within the same (i.e. rail-rail) or different (i.e. sea-rail) transport connections. The new service route should be as much as innovative in terms of reducing transport time and transport cost and increasing transport reliability and so that it should provide also a high degree of transport route performance. The company has assigned three experts intern for decision-making, who searched all possible routes between OD and determined 17 alternative routes, where any given transport unit (cargo) might have been transshipped (modal shift) one or two times.

#	OD	Node (n1)	Leg (l1)	Node (n2)	Leg (l2)	Node (n3)	Leg (l3)	Node (n4)	Time (day)	Cost (€)	Reliability (%)
1	Pendik-Kiel	Pendik	Sea	Trieste	Rail	Kiel	n/n	n/n	4	3298	90
2	Pendik-Hamburg	Pendik	Sea	Trieste	Rail	Vienna	Rail	Hamburg	6	2958	86,7
3	Pendik-Hamburg	Pendik	Sea	Trieste	Rail	Linz	Rail	Hamburg	6	3078	86,7
4	Istanbul-Hamburg	Istanbul	Rail	Köln	Rail	Hamburg	n/n	n/n	6	2750	75
5	Pendik-Hamburg	Pendik	Sea	Trieste	Rail	Kiel	Rail	Hamburg	6	3448	85,0
6	Pendik-Hamburg	Pendik	Sea	Trieste	Rail	Köln	Rail	Hamburg	6	3298	83,3
7	Pendik-Hamburg	Pendik	Sea	Trieste	Rail	Salzburg	Rail	Hamburg	7	2898	86,7
8	Pendik-Hamburg	Pendik	Sea	Trieste	Rail	Duisburg	Rail	Hamburg	7	3398	80,0
9	Pendik-Hamburg	Pendik	Sea	Trieste	Rail	Milano	Rail	Hamburg	7	2561	86,7
10	Istanbul-Kiel	Istanbul	Sea	Trieste	Rail	Kiel	n/n	n/n	5	3213	87,5
11	Istanbul-Hamburg	Istanbul	Sea	Trieste	Rail	Linz	Rail	Hamburg	6	2993	85,0
12	Istanbul-Hamburg	Istanbul	Sea	Trieste	Rail	Salzburg	Rail	Hamburg	6	2813	85,0
13	Istanbul-Hamburg	Istanbul	Sea	Trieste	Rail	Vienna	Rail	Hamburg	6	3113	85,0
14	Istanbul-Hamburg	Istanbul	Sea	Trieste	Rail	Duisburg	Rail	Hamburg	6	3313	78,3
15	Istanbul-Hamburg	Istanbul	Sea	Trieste	Rail	Ludwigs-hafen	Rail	Hamburg	6	2913	85,0
16	Istanbul-Hamburg	Istanbul	Sea	Trieste	Rail	Milano	Rail	Hamburg	6	2476	85,0
17	Istanbul-Hamburg	Istanbul	Sea	Trieste	Rail	Budapest	Rail	Hamburg	7	2613	78,3

Table 1: The list of available multimodal routes between origin and destination

In this case study, the multimodal networks include rail and sea freight routes which are operated by MTP from one terminal or from one port to another terminal or port in main-haulage and the routes can compose of several legs and nodes (transfer station). The total multimodal freight route can be designed by using both sea and rail ways or either of them. Table 1 lists the available 17 multimodal routes from Istanbul to Hamburg with one as well as two transshipments. Three routes, namely from Pendik to Kiel (#1) and from Istanbul to Kiel (#10) via sea-rail connections and from Istanbul to Hamburg (#4) via rail-rail connections contain one transshipment, where Trieste and Köln are transfer terminals to change the transport mode from sea to rail and vice versa or from rail to rail. The rest of routes obtain two transshipments, e.g. between Pendik-Hamburg, the first transshipment from sea to rail takes place in Trieste and the second one is from rail to rail in Vienna. The

number of transshipments can be calculated by  $n - 2$ , where  $n$  is the total number of nodes in multimodal transport network.

A major concern is obtaining the performance availability of entire multimodal transport systems by taking into account only some parameters, due to the fact that performance availability cannot be evaluated easily with the help of a deterministic function of transport time, transport cost and transport reliability. However, the accurate performance availability values of whole systems cannot be assured using simple equations. Besides that, the correlation between control parameters and performance availability is too challenging to express with a mathematical function. Because of this, formulating the performance availability manner can be achieved by using the Fuzzy-Logic rules (Mahmoudi et al., 2012).

In this fuzzy system, as part of the present study, three inputs parameters, namely: transport time and transport cost and transport reliability, and one output parameter, namely: route performance are determined, seen in Figure 1. In the model input parameters are given, whereas output parameter(s) will be calculated to make route selection decision. The descriptions of input parameters are as follows: *Transport time* denotes the total traveling days for any trip between OD. *Transport cost* includes the total cost of rail and/or sea transport from/to port to/from terminal or vice versa, loading/unloading costs, terminal/port customs costs and other relevant costs. *Transport service reliability* is associated with the percentage of transport services reaching their destination on time (on time arrival). Especially rail services have difficulty to complete their trips without having any delay because of the highly-congested rail network, moreover rail services obtain less operational flexibility than other services. In order to overcome operational difficulties, leading railways are using digital technologies to build timetables and control the network in ways that raise reliability even as train frequency increases. The output parameter of *route performance* is key to evaluating and ensuring timely multimodal services. If it performs poor, transport planners can decide to stop daily operations for the related route or if it realizes a high performance, then the transport service can invest more to maximize its profits.

The fuzzy set of output and input parameters are given in Figure 3, where the membership functions ( $\mu_x(x), \mu_z(z), \mu_y(y), \mu_u(u)$ ) are generated by determining five linguistic variables for transport cost, transport time and route performance, namely; Very Low (VL), Low (L), Medium (M), High (H) and Very High (VH). However, the transport reliability parameter includes only three linguistic variables, which are Low (L), Medium (M) and High (H). The range of membership functions and max/min inference are determined by expert opinions, where transport cost varies between € 2300-3800 by 300 intervals and transport time is ranged between 3-8 days with 1 interval, whereas transport reliability and route performance varies between 0-100% with 25 intervals. Because of the max/min inference, membership functions are overlapped by pairs.

For this research, a set of seventy-five fuzzy “if-then” rules are determined by expert opinions, which are the multiplication of five linguistic terms of transport cost and transport time, and three linguistics terms of transport service reliability. One example of these rules could be given as follows:

IF	Transport Cost = Very Low (VL), and Transport Time = Very Low (VL), and Transport Reliability = Medium (M)
THEN	Route Performance = Medium (M)

A complete list of fuzzy “if-then” rules is given in the Appendix, where cost, time and reliability denote “if part”, whereas route performance indicates “then part” of the fuzzy rules.

Fuzzy Logic evaluation is processed using a program developed in Visual Basic (VB) programming language embedded in Excel Macro which enables to perform advanced calculations with the spreadsheet and also simplifies the connection between user interface and database. The data set of the combinations for different transport cost, transport time and transport reliability rate of 17 pre-defined multimodal freight routes is entered into the Excel calculation system (the complete list can be seen in Table 1), in the meantime another data set for fuzzy rules and membership functions for input and output parameters are entered into the system, afterwards the VB macro run and it created a data set of entire route performance.

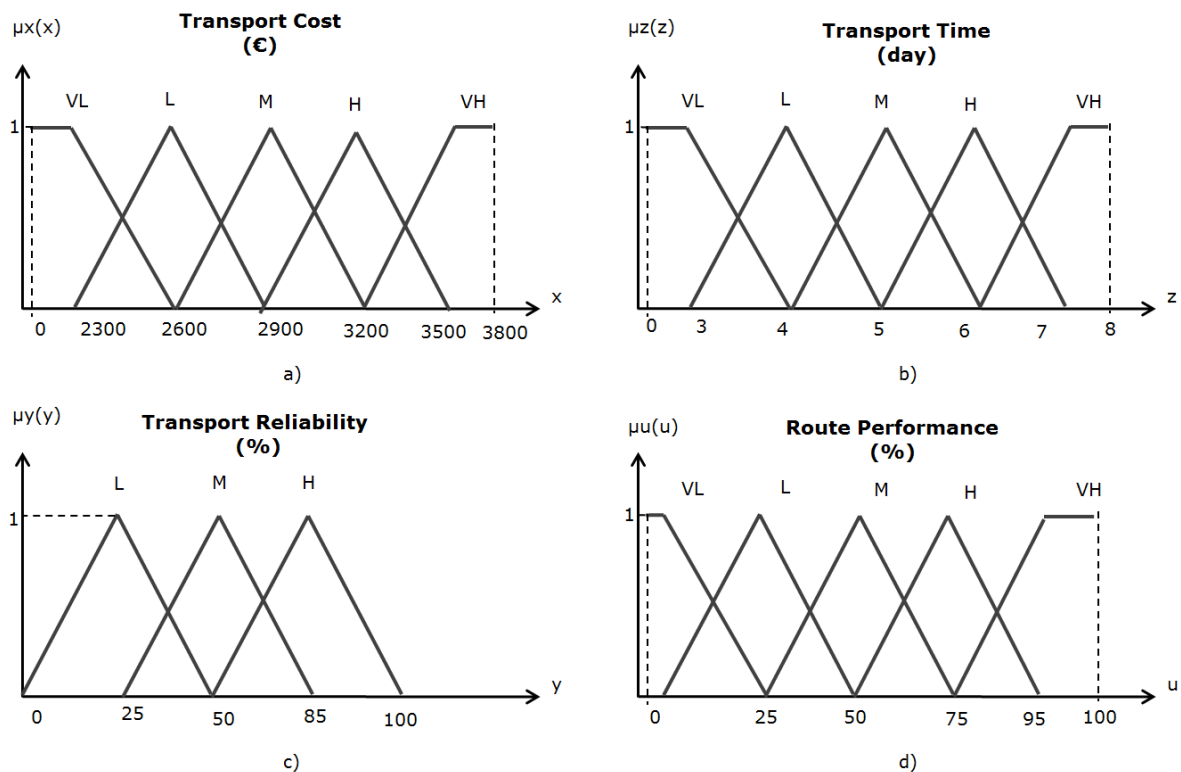


Figure 3: The fuzzy set of output and input parameters for case study.

## FINDINGS AND CONCLUSION

The result of performance availability calculated through the Fuzzy Logic algorithm is provided in Figure 4. Three out of 17 multimodal freight routes achieved the higher performance according to program result, respectively: the routes for Istanbul-Kiel (#10) with 84%, Istanbul-Hamburg (#15) with 81% and Istanbul-Hamburg (#17) with 80% route performance. The semi-trailers between Istanbul-Kiel have been transshipped one time, whereas the cargoes between Istanbul-Hamburg have been transshipped two times. So that we could also say that the number of transshipments have an influence on route performance, as during the modal transfers, because of some reasons (e.g. lacking infrastructure, capacity issues etc.) delays and cancellations might occur, however containerization, standardizing sizes and features can reduce multimodal transfer times and increase cost and fuel efficiency, also automated transfer management systems (like ModaLohr, Flexiwaggon, Megawing, ISU etc.) can streamline multimodal transfer processes and maximize efficiency in platforms, this structure can improve the route performance as well. MTP can decide on one of the three highest performed routes and while deciding on one route, the others might be considered as alternatives, if any interruption on the selected route occurs. In this case study as a result, the freight route is selected as a new multimodal freight service route between Istanbul-Kiel, and the other two routes between Istanbul-Hamburg will be considered as alternative route options. At the end, the result of route performance can be interpreted that the higher the level of route performance, the

greater the selection of the multimodal freight route and the higher the willingness of MTPs to offer this to shippers' use.

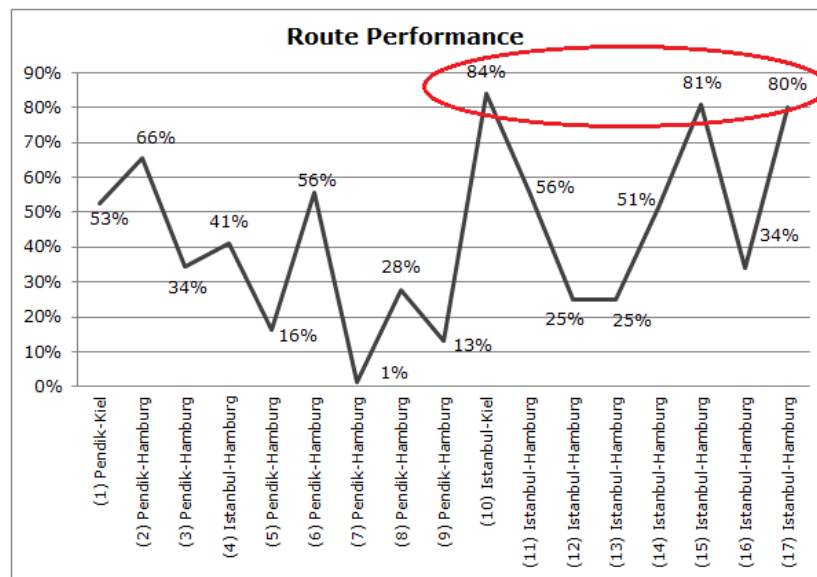


Figure 4: Route Performance of alternative routes

In this research paper, the Fuzzy Logic is used to solve the route selection problem for multimodal transport. Although, Fuzzy Logic modelling is becoming more and more widespread in various domains and disciplines to solve complex problems, it contains some limitations, as the obtained results depends heavily on the quality of selected parameters and expert opinions to determine "fuzzy-rules" and min/max inference. This methodology is applied for the first time in multimodal route selection problem which is solved by using three input and one output parameters. In the future research, the other route selection parameters such as transport risk, road structure, accident conditions, transport volume, distance can be used to enlarge the scope of the model. In addition, the road transport can be added into the model, so that the obtained data analytics according to OD flows might help to determine where hinterland terminals for sea and rail transport are located.

## ACKNOWLEDGMENTS

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## APPENDIX: Fuzzy rule base from the experts' opinions

Rule Number #	If part			Then part	Rule Number #	If part			Then part
	Cost (€)	Reliability (%)	Time (day)	Performance (%)		Cost (€)	Reliability (%)	Time (day)	Performance (%)
1	VL	L	VL	M	39	M	M	H	L
2	VL	L	L	M	40	M	M	VH	L
3	VL	L	M	L	41	M	H	VL	VH
4	VL	L	H	L	42	M	H	L	VH
5	VL	L	VH	VL	43	M	H	M	H
6	VL	M	VL	VH	44	M	H	H	M
7	VL	M	L	H	45	M	H	VH	L
8	VL	M	M	M	46	H	L	VL	L
9	VL	M	H	L	47	H	L	L	L
10	VL	M	VH	L	48	H	L	M	VL
11	VL	H	VL	VH	49	H	L	H	VL
12	VL	H	L	H	50	H	L	VH	VL
13	VL	H	M	H	51	H	M	VL	M
14	VL	H	H	H	52	H	M	L	M
15	VL	H	VH	M	53	H	M	M	L
16	L	L	VL	M	54	H	M	H	VL
17	L	L	L	M	55	H	M	VH	VL
18	L	L	M	L	56	H	H	VL	H
19	L	L	H	L	57	H	H	L	M
20	L	L	VH	L	58	H	H	M	M
21	L	M	VL	H	59	H	H	H	L
22	L	M	L	H	60	H	H	VH	VL
23	L	M	M	M	61	VH	L	VL	L
24	L	M	H	M	62	VH	L	L	L
25	L	M	VH	L	63	VH	L	M	VL
26	L	H	VL	VH	64	VH	L	H	VL
27	L	H	L	H	65	VH	L	VH	VL
28	L	H	M	H	66	VH	M	VL	L
29	L	H	H	H	67	VH	M	L	L
30	L	H	VH	M	68	VH	M	M	L
31	M	L	VL	M	69	VH	M	H	VL
32	M	L	L	L	70	VH	M	VH	VL
33	M	L	M	L	71	VH	H	VL	M
34	M	L	H	VL	72	VH	H	L	L
35	M	L	VH	VL	73	VH	H	M	L
36	M	M	VL	M	74	VH	H	H	VL
37	M	M	L	M	75	VH	H	VH	VL
38	M	M	M	M					

Legend: Very Low (VL), Low (L), Medium (M), High (H), Very High (VH).

# PERFORMANCE MEASUREMENT FRAMEWORK FOR THE OIL AND GAS SUPPLY CHAIN

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## **Abstract**

### **Purpose of this paper:**

The aim of this paper was to explore the prevalence of the use of performance measures in the oil and gas industry and their impacts on organisational performance.

### **Design/methodology/approach:**

A questionnaire survey was designed with a set of performance measures that was developed based on earlier a combination of literature review and exploratory interview of practitioners. These measures comprise of financial measures, operational measures, safety measures, environmental and social responsibility measures. The questionnaire was distributed amongst 550 oil and gas companies in the UK and 120 companies in Malaysia. The response rate was 17%. A correlation analysis was conducted using SPSS to evaluate the impact of the choice of performance measures on the actual organisational performance.

### **Findings:**

This study reveals the prevalence of performance measures in the Oil and Gas industry based on the level of importance. In addition, it shows that performance measurement framework has a significant positive correlation with the overall organisational performance.

### **Value:**

As little research has been conducted on performance measurement within the oil and gas industry, these findings provides additional insights into the usage and roles of performance measurement in the industry. Further research can be conducted to investigate the most influential measures in determining overall organisational performance in this industry.

### **Practical implications:**

This study provides some guidance to practitioners with regards to the potential of specific measures in enhancing overall organisational performance.

## **1. Introduction**

Despite the discovery of alternative energy, oil and gas are still the major sources of energy today (Energy and environment in the European Union, 2006). In fact, to replace 100% of oil and gas sources will require huge increases in alternative energy productions. The current global consumptions of energy from fossil fuels (oil and gas) is around 15 terrawatts (TW), whilst the present renewable energy (including large hydro) alternatives only produce around 1TW. This is not considering the projections of global energy demands by 2050, which will be around 25- 30TW (Lloyd and Subbarao, 2009)

In comparison to other industries, oil and gas have many distinguishing characteristics, such as bigger project size, higher technical complexities, involvements of diverse expertise, high transportation and machinery costs (Varma, Wadhwa and Deshmukh, 2008; Chima, 2011). Therefore, oil and gas operations usually involve multiple companies of varying sizes to complete their project executions. The integration between these companies can be in a form of joint-venture or by subcontracting part of the scope of their work. This supply chain integration is required to share the risk, cost, expertise, or a combination of these (Ernst & Young, 2014; Organisation Petroleum Exporting Countries, 2015). In



addition, the industry has very long supply chain links involving many parties from the exploration of oil and gas to the ultimate customer (Dawe, 2000; Hyne, 2012; Havard, 2013). The complexities of the oil and gas supply chain, geopolitical issues (Jobling and Jamasb, 2015; Khan, 2016), and fluctuation of oil and gas prices all combined can significantly affect the performance of oil and gas companies. Since these factors are very least controlled by oil and gas companies, one way to deal with them is by focusing on internal and external supply chains to enhance their performance. Supply chain performance has been recognised as major determinant of organisational productivity and profitability (Gunasekaran, Patel and McGaughey, 2004; Kannan and Tan, 2005; Chang *et al.*, 2016). To ensure effectiveness and efficiencies of the supply chain management, an appropriate performance measurement framework should be in place. Therefore, this study will investigate the performance measurement framework for the oil and gas supply chain. Specifically, it will present the prevalence of performance measures for this industry and impacts on actual organisational performance.

Resource based view (RBV) theory was used as the basis to explain this research. RBV theory focuses on achieving competitive edge by focusing on internal resources and capabilities (Coates and Mcdermott, 2002). RBV emphasise that competitive advantage can be sustained if the capabilities creating the advantage are supported by valuable, rare, non-transferable, and difficult to replicate resources (Peteraf, 1993; Hart, 1995). The final products of the oil and gas companies has very minimal differentiation for them to attain competitive edge through it. For that reason, it is important for them to shift their focus to internal factors to distinguish themselves from their competitors. Therefore, in this research, performance measurement is viewed as a 'resource' in attaining competitive advantages.

## **2. Literature review**

Nowadays, with increasing reliance of outsourcing activities, there is the need for companies to emphasise improvement in supply chain performance (Lambert and Cooper, 2000; Fernandes, Barbosa-póvoa and Relvas, 2010; Wildgoose, Brennan and Thompson, 2012). In line with this, research on supply chain performance that focuses on various contexts of supply chain management has gained attention of both academics and practitioners. Several studies have been undertaken to investigate and propose performance measurement framework for manufacturing and services industries (Bourne, 2000; Davis and Albright, 2004; Sambasivan, Mohamed and Nandan, 2009; Khani and Ahmadi, 2012; Cheng, Lee and Chen, 2014; Lucato *et al.*, 2014). However, performance measurement in the oil and gas context is under researched. Some of the existing study on supply chain performance for this industry concerned sustainability measures (Yusuf *et al.*, 2013, 2014). Varma, Wadhwa and Deshmukh (2008) in particular explored the prevalence of performance measures in the oil and gas supply chain. However, it only focused on the downstream petroleum refining sector of the industry. More importantly, it did not investigate choice of performance measures or usage of performance measures and impacts on organisational performance. In addition, the need for this study also comes from the fact that performance measurement framework is influenced by the type of industry in which organisations operate (Otto and Kotzab, 2003; Gunasekaran and Kobu, 2007; Kumar and Markeset, 2007; Hsu *et al.*, 2009; Kumar and Nambirajan, 2013). As such, this research attempts to study the prevalence of performance measures of the oil and gas supply chain and its implications on the organisational performance.

## **3. Research approach**

This research adopted survey by questionnaire developed from literature review and in-depth interview with five supply chain experts drawn from five organisations within the industry. A total of 21 performance measures were listed in the

questionnaire with 16 organisational performance attributes. The performance measures and organisational performance attributes comprise of financial, operational, safety, environmental and corporate social responsibility measures. The questionnaire was validated by academics and practitioners. Subsequently, the questionnaire was mailed together with paid envelope and cover letter to the CEO of companies in the UK. In addition, electronic survey by email was used for the CEO of companies drawn from Malaysia. The correlation between performance measures and organisational performance was analysed using SPSS. Table 1 shows the demographic profile of the respondents consisting of size of the organisations, respondents' designations, major business sectors and proportion of the UK and Malaysia responses.

**Table1:** Demographic profile of respondents

<b>Total number of respondents</b>	<b>Frequency</b>	<b>Percentage</b>
<b>Size by number of employees</b>		
Less than 50	50	50%
51 -200	19	19%
201 – 500	12	12%
501 – 1500	8	8.0%
1501 – 3000	3	3.0%
Above 3000	5	5.0%
Total	97	97%
<b>Designation of respondents</b>		
MD/ CEO/ CFO/ Director	29	30.5%
Manager: Supply chain & contracts	15	15.8%
General Manager/ Country Manager/ Business Development Manager	11	11.6%
Manager: Technical / Operations	12	12.7%
Executive: Procurement/ Contracts specialist	10	10.5%
Engineer: Project/ Process/ Cost	5	5.3%
Executive (others)	2	2.1%
<b>Major business sectors</b>		
Exploration and production	20	13.6%
Marine and subsea services	25	17%
Energy consultancies including geographical consultancies	12	8.2%
Transportation, storage, logistics, catering and allied services	17	11.6%
Well and drilling services	13	8.8%
Engineering services, facilities management, structure designs and fabricators	39	26.5%
Refining, refined oil distribution and marketing	13	8.8%
<b>Other services:</b>		
Decommissioning	3	2%
Repair and Maintenance	2	1.4%
Trading and supply	3	2%
<b>Country</b>		
UK	62	61.4%
Malaysia	38	38.6%

#### *Preliminary analysis of data*

A reliability analysis using Cronbach alpha test was conducted to determine the internal consistency of the survey instrument. This involves overall questionnaire, performance measures, and organisational performance. The Cronbach alpha value for overall questionnaire was 0.909, performance measures was 0.893, and organisational performance was 0.764. These reliability test values show a strong internal consistency of the research instrument (Sekaran and Bougie, 2013). T-

test analysis was conducted by comparing the first 50% of respondents and the last 50%, which were considered as non-respondents. The results show that the null hypothesis that there is no significant differences in the mean values between the first wave and the second for the size of companies (number of employees) and the organisational performance cannot be rejected. This indicates that there is no non-response bias.

#### 4. Results and discussion

The research variables were assessed by five-point Likert-scale ranging from very low to very high for performance measures, and strongly disagree to strongly agree for organisational performance attributes.

##### *Prevalence of performance measures in the oil and gas industry*

The performance measures were ranked based on the mean values as in Table 2. Safety compliance was found to be the most important performance measure (4.59) followed by services/ product quality (4.48) and product and services reliability (4.39). This is in line with previous research on performance measurement, which suggests that customer satisfaction is the main focus of the organisation. Chen et al., 2013; Varma et al., 2008b; Gunasekaran et al., 2004 argued that quality and reliability are the main enabling factors in achieving customer satisfaction.

**Table 2:** Level of importance of performance measures

Ranking	Performance measures	Mean	Mode	Frequency
1	Safety compliance	4.59	5	63
2	Product/ services quality	4.48	5	55
3	Product/ services reliability	4.39	4	48
4	Cost saving	4.33	5	45
5	Flexibility in meeting customers' needs	4.29	4	45
6	Safety training	4.29	5	46
7	Timeliness	4.21	4	59
8	Return on investment	4.18	4	53
9	Process compliance	4.14	4	49
10	Ethical business	4.12	4	45
11	Supplier reliability	4.09	4	57
12	Accuracy of schedule	4.08	4	57
13	Supplier flexibility	3.92	4	50
14	Environmental pollutant control	3.88	4	43
15	Forecast accuracy	3.85	4	57
16	Reduction of waste	3.68	4	48
17	Technology innovations	3.62	4	37
18	Innovation in operations	3.59	4	40
19	Supplier compliance on social responsibilities policy	3.58	4	42
20	Number of innovation ideas generated	3.45	4	39
21	Investment in charitable programmes	3.08	3	48

Even though safety compliance was not widely discussed in supply chain research, it is recognised as the most important measure in the oil and gas industry due to their high exposure to risks. Safety compliance is also important in enhancing customers' perspectives in this industry. This measure is also driven by various external factors particularly, the local content requirement by host government, the stakeholders' expectations, and social responsibility pressures driven by the non-government organisations. In essence, safety compliance is a measure that is

motivated by both internal and external factors. It can be observed that cost savings was the fourth-ranked factor which contrasts with previous research in which Yusuf et al., (2014) found that Oil and Gas organisations perceived competing through cost as their least consideration. The factor of cost savings is not considered crucial in attaining competitive edge given the nature of huge profits in this industry, especially at times of high oil prices. Thus, the focus on cost measure in this study may be driven by the current drop in oil prices. The current depressed market environment has left oil and gas industry with no choice but to enhance their cost savings efforts. On the other hand, the least important performance measure is 'Investment in charitable events'. The distribution of respondents' organisation based on the number of employees could explain this finding where the majority of them were small and medium companies. Therefore, it can be adduced that they have limited financial resources to devote to charitable activities and even for the larger organisations, current low oil price could also affect the level their financial allocations for charitable ventures. The table also suggests that most of the innovation measures were ranked among the least important performance measures. This is because, unlike other industries, like automotive, electronic, and fashion (Sukwadi et al., 2013), the final products/services of the oil and gas industry has very minimal differentiation (Chima and Hills, 2007).

*The relationship between the choice of performance measures and overall organisational performance*

Table 3 reports the outcomes of the correlation analysis between performance measures and aggregated organisation performance.

**Table 3:** Correlation analysis between performance measures and overall organisational performance

Performance measures	Organisational performance
PM1 Cost savings	NSC
PM2 Return on investment	.248*
PM3 Accuracy of schedule	.359**
PM4 Timeliness	.313**
PM5 Product/ services reliability	.450**
PM6 Supplier reliability	.257**
PM7 Flexibility in meeting customers' needs	.417**
PM8 Supplier flexibility	.382**
PM9 Products/ services quality	.389**
PM10 Forecast accuracy	.347**
PM11 Process compliance	.527**
PM12 Innovation ideas generated	.377**
PM13 Innovation in operations	.561**
PM14 Technology innovations	.529**
PM15 Environmental pollutant control	.320**
PM16 Reduction of waste	.387**
PM17 Safety compliance	.371**
PM18 Safety training	.440**
PM19 Supplier compliance on social responsibilities policy	.367**
PM20 Ethical business	.211**
PM21 Investment in charitable programmes	.394**
*Correlation is significant at .05 levels (2-tailed). **Correlation is significant at .01 levels (2-tailed).	

Out of twenty-one performance measures, PM13: innovation in operations demonstrates the highest correlation value (0.561) with overall organisational performance. This is followed by PM14: technology innovation (0.529). This implies that organisations focusing on innovation measures provide greater impact on the overall organisation performance. The application of innovation measures in a PMF has been widely discussed in previous research (Bhagwat and Sharma, 2007; Yeh, Cheng and Chi, 2007; Varma, Wadhwa and Deshmukh, 2008; Thakkar, Kanda and Deshmukh, 2009; Halman and Voordijk, 2012). Terziovski (2010) demonstrated a positive impact of innovation strategy on the performance of SME manufacturers in Taiwan. A study by Yang (2012) shows positive relationship between innovation capabilities and supply chain performance.

The third highest correlation was shown by PM11: process compliance (0.527). A possible explanation for this is that an organisation that emphasises process compliance is presumed as having a well-structured governance. Therefore, most of the aspects of performance in these organisations received considerable attention from managers which in turn led to better performance. To support this, Bauer *et al.* (2008), on corporate governance in Japan, demonstrates that well-governed organisations outperform loose-governed counterparts by 15%. In addition, Andreou, et al (2014) show that there is a positive association between corporate governance and organisational performance..

## 5. Conclusion

The understanding of the prevalence of performance measures in this industry provides insights into the reality of performance management in the oil and gas industry. Safety compliance is considered as the most widely used performance measure in this industry followed by product/ services quality, product/services reliability, and cost savings. On the other hand, investment in charitable organisations is the least important performance measure - this could be due to the fact that this measure is more common in the large organisations which have the least representation in our sample as there are not many of them in the industry. From this research, it can be inferred that a performance measurement framework has a significant positive impact on the overall organisational performance. The results reveals which performance measures have better associations with the overall organisational performance. The organisation, which focuses on innovation measures enhance their innovation performance and subsequently, the overall organisational performance. This study supports prior research by Yusuf, Gunasekaran, et al., (2014) who posited that innovation performance improvement in this industry can be achieved through innovation and risk taking. The study found that innovation measures are the most influential measures in determining organisations' success and gaining competitive advantage. However, this performance measure is not widely used in the industry. Process compliance also indicates a strong association with overall organisational performance ( $>0.5$ ). This measure is very much related to measuring corporate governance of an organisation. Thus, an organisation that has a well-structured corporate governance in this industry demonstrates a better organisational performance. Again, this measure was ranked as the ninth most important performance measure. This research contributes to the body of knowledge and general literature on the supply chain performance management from the oil and gas context. Also, it provides some guidance to the practitioners with regards to the potential of specific measures in enhancing organisational performance.

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# MANAGING ILL-FORMED DATA TO IMPROVE SUPPLY CHAIN MANAGEMENT PERFORMANCE

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## Abstract

**Purpose of this paper:** The global logistics industry generates numerous data from its operations such as a factory's inventory, transportation cost, warehouse activity, and retail store returns. This dataset can be used for operational capacity planning, service improvement, market intelligence, and so on. However, the datasets are not always well behaved or well defined sometimes. Furthermore, the size of the datasets can be huge or sometimes insufficient for analysis. These datasets need to be cleansed for analysis and there is no standard way of doing so. Hence, there is a real need to design robust and efficient methods to analyse and make better sense of poorly formed data for judicious use in improving supply chain performance.

**Design/methodology/approach:** In this paper, we study the different ways to make good and quick sense of the available data in a supply chain. We will choose an example dataset. We perform data cleansing and pre-processing of the dataset (Han et al., 2012). Next, we apply robust methods such as Hellerstein's (2008) robust statistics, ratio analysis, and multi-variate non-parametric tests on the cleansed dataset to show the applicability of such methods. We also apply model based learning techniques (Arburto and Weber, 2007) such as ARIMA, fuzzy neural networks, and machine learning. We explore the use of Microsoft Excel and Matlab platforms to implement these techniques in a practical operational setting for industry to use.

**Findings:** The trained neural network method for data analysis gives better forecasts as compared to the traditional regression methods. We show that taking the demand correlation of dependent products is also useful for mitigating any data inadequacy in the supply chain

**Value:** This paper provides some novel ways of analysing poorly formed data, which is often the case for many firms. This moves the paradigm away from the need for relying on large datasets to improve supply chain performance. Our method is faster, less costly, less data dependent, and reduces the degree of data pollution. The improved demand forecasting approach using moving average and machine learning models from our work can help academia to push the frontier of research in this space.

## 1. Introduction

The global logistics industry generates numerous amounts of transactional data at all nodes in the supply chain from its operations such as a factory's inventory, supplier's incoming materials, transportation cost, warehouse activities, and retail store returns. This dataset can be and is often used meticulously for operational capacity planning, service improvement, gathering market intelligence on customers and competitors, product and service parts demand forecasting, and so on. Exploited wisely, such data is of immense competitive advantage in helping the actors in the supply chain to improve their operations and increase profitability. The extant literature contains much work in this realm (e.g. Ko, Tiwari and Mehnen, 2010; Jaipuria and Mahapatra, 2014). Indeed, knowing market demand and supply well can accurately support efficient supply chain



scheduling, better inventory management to reduce excess stock and keep working capital in check, leaving customers satisfied through high on-shelf availability.

However, the datasets are not always well behaved, understood or even well defined sometimes. Further, the size of the datasets can also be overwhelmingly huge (Johnson and Dasu, 1998) for a supply chain planner to handle, or the quality of the input data is found wanting especially when the data is ill-formed to begin with. By ill-formed, we take it to mean that the data provided to the system is patchy or unreliable. Indeed, today, there is literature which investigate the aspect of improving supply chain performance by using hybrid demand forecasts to reduce the bullwhip effect (Aburto and Weber, 2007; Jaipuria and Mahapatra, 2014). Between the twin challenges of data overload (leading to information flow overload in the supply chain) and poorly formed data (leading to unreliable information flow in the supply chain, and a host of other supply chain problems such as the bullwhip effect), it is often the latter that calls for rigorous investigation by industry to design better, cheaper, and faster ways of harnessing such data to improve the performance of the supply chain overall.

Quite often, these datasets would need to be cleansed or scrubbed properly before it can be mined or analysed adequately for pertinent information and knowledge. However, there is no standard way to do so, and this process can also be rather onerous and time consuming. Hence, there is a practical need to design robust and efficient methods to rapidly analyse and make better sense of poorly or ill-formed data for judicious use by the supply chain planners in improving overall supply chain performance.

Many scholars have extensively investigated the challenge of data analytics and provided numerous techniques (see, e.g., Johnson and Dasu, 1998). Some of these techniques are extensively sophisticated (Choi, Yu and Au, 2011) while others are elaborate and targeted at certain parts of the supply chain (Ampazis, 2015). However, not much have been discussed about ill-formed data being provided by the users themselves. Therefore, it is timely to put forth some useful data driven techniques to show the reader how data analytics need not always involve large datasets which require intensive mining nor abandon ill-formed data when we see one.

In what follows, we will rely on an actual case company to provide some evidence of how we propose to manage ill-formed data for improving supply chain performance. The rest of this paper is organized as follows. Section 2 presents the research method which involves data collection, data cleansing to remove inconsistencies or human errors, and correlational analysis of the data of interest. We have also explored the use of the existing industry data analysis libraries and tools based on Excel, Matlab, and R. This is then followed by Section 3, in which we will look at some of the techniques applicable to demand forecasting. Section 4 presents the results and the discussions. In this Section, we applied four methods available for demand forecasting by taking an example dataset provided by the case company. Specifically, we looked at the quality of prediction, how easily it can be applied, the assumptions of the method, and the size of data required. Finally, Section 5 concludes with some directions for further investigation.

## **2. Method**

There are many modern analytics methods such as neural networks, SVM (support vector machine) regression, and reinforcement learning which can be successfully used to overcome the concerns of ill-formed data and provide a reasonably high accuracy in trend prediction. The performance of these methods varies with the dataset and needs to be compared to find the best results (Thissen et al., 2003). With increasing market complexity, hybrid methods are being developed such as combining ARIMA and neural

networks (Aburto and Weber, 2007), and adaptive neural fuzzy systems to benefit from the advantages of the different methods.

In this paper, we study the different ways to make good and quick sense of the available data for a supply chain. We choose example datasets taken from an actual operating concern of a large scale healthcare logistics operator. In particular, we have extracted the demand and supply datasets of a business unit of a healthcare logistics service provider headquartered in Singapore, named in this paper as Firm XYZ. Following the literature, we perform the necessary data cleansing (Dasu and Johnson, 2003) and pre-processing of the dataset (Han et al., 2011). Next, we apply the robust methods proposed by established scholars (Hellerstein, 2008) such as robust statistics, ratio analysis, and multi-variate non-parametric tests on the cleansed dataset to show the applicability of such methods. We also apply model based learning techniques (Aburto and Weber, 2007) such as ARIMA, fuzzy neural networks, and machine learning. In addition, we explore the use of the Microsoft Excel and Matlab platforms to implement these techniques in a practical operational setting for industry to use.

## **Dataset**

The dataset is of a supply chain of general medical consumable goods such as syringes, masks, gloves, dressing sheets, and diapers. There are 28 products and 60 healthcare-institution customers and the dataset contains 21 months of transactional data. The demand and supply values are logged for each day, for each customer, and for each product individually. For our analysis, we took the data points as the weekly demand of a product, so we had 92 weekly demand sample points for analysis.

## **Data cleansing**

On exploring the dataset provided by Firm XYZ, it was found that the dataset may not be directly and immediately useable for analysis as some logistics data values were missing, inconsistent, too many outliers or and there was evidence of very noisy data as shown by spectral analysis using Microsoft Excel. If these are not identified and treated, then it may give rise to wrong or poor quality results in subsequent analysis and the results cannot be relied upon (Han et al., 2011).

Possible solutions for the treatment of missing values are to ignore the tuple, fill in the values manually if there are not many, or use a central tendency attribute such as the median or mean of nearby values to fill it, or if we are able to formulate the distribution of the data with a known distribution or regression then we can find the value and populate the dataset accordingly. A point of note here is that a missing value is not always an error, it depends very much on the attributes of the dataset; whether it is valid or not. In our example dataset, it is possible that there was no demand from a customer on certain days (and hence a zero data entry, leading to sparse data). Therefore, we filled this missing value with a zero value.

At the same time, the dataset had non-positive values, as there were obvious data entry errors in some instances. As we were dealing with demand data, we would consider these spurious data points as inconsistencies i.e. negative values in the demand data or non-integer values at integer places in the dataset would need to be corrected or removed.

On the treatment of the outliers, a typical and practical definition of an outlier would be the points that differ from mean by more than 2 standard deviations either way. However, as the mean and standard deviation are themselves affected by the outliers, a very large single erroneous value can increase the mean value significantly. Thus, a better option would be to use the median which is the mid value of the entire data and the error in 50% or more of the dataset needs to be there for an arbitrary shift in the median. According to Hellerstein (2008), the median is more stable than the mean for

use in our dataset. A modified median can be used by ignoring some boundary values on both sides of the dataset if those values are less likely to occur. However, this modification depends on the requirement of the analysis and the dataset. Similarly, a robust analogy for the standard dispersion of the data is the median absolute deviation. Using these robust statistical attributes, the outliers in the data can be studied. If we can fit a distribution onto a dataset, then the points deviating significantly from the curve can be identified. However, a large deviated value in the supply chain data is also possible because of seasonality and these cannot be simply treated as outliers. This possibility needs to be accounted for before classifying any values as outliers.

To decrease the noise in the data, established techniques such as the moving average and regression are used, other than the histogram binning which is used to smooth the sorted data. Using binning under Excel, the values are distributed in bins of size 3-4, and then all the points in a bin are replaced by same value mean, median, boundary value or some other attribute, so as to form the required distribution for further analysis.

### Correlation analysis

The scatterplots in Excel provided visual evidence of correlation in the demand movement of the customers or between two products for the same customer. We computed the correlation between the products such as gloves and gowns, and syringes and needles to see the degree of correlation. Similarly, we computed the correlation between the demands of customers x and y for each product, using the formula,  $r_{xy} = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2}}$ .

### 3. Demand prediction techniques

There are many statistical and machine learning models which can be used for demand prediction. We now provide the models that we have studied and compared their performance by applying it on the example dataset.

#### Auto regressive integrated moving average (ARIMA) (ARIMA, 2017)

The ARIMA forecasting model is a linear model which does predictions based on the past values of the dependent variable (time series) and forecast errors. For instance, for the non-seasonal ARIMA model, ARIMA(p, d, q) is a discrete time-linear equation of the form

$$\left(1 - \sum_{k=1}^p \alpha_k L^k\right) (1 - L)^d X_t = \left(1 + \sum_{k=1}^q \beta_k L^k\right) \epsilon_t$$

where L is the lag operator, i.e.,  $LX_t = X_{t-1}$ ,  $\alpha_k$  are the parameters of the autoregressive part of the model,  $\beta_k$  are the parameters of the moving average part of the model, p is the number of time lags, q is the order of the moving average model, and  $\epsilon_t$  are the error terms.

If we denote the term  $(1 - L)^d X_t$  as  $Y_t$ , then it transforms into the ARMA(p,q) model i.e.

$$\left(1 - \sum_{k=1}^p \alpha_k L^k\right) Y_t = \left(1 + \sum_{k=1}^q \beta_k L^k\right) \epsilon_t$$

$$Y_t = \alpha_1 Y_{t-1} + \dots + \alpha_p Y_{t-p} + \epsilon_t + \beta_1 \epsilon_{t-1} + \dots + \beta_q \epsilon_{t-q}$$

which is just a weighted sum of the past values of the dependent variable (demand)  $Y_t$ , and the error terms.

The underlying assumption in ARIMA models is that the time series being analyzed is stationary i.e., the statistical properties of it does not change over time or the autocorrelation is same. By taking the difference  $X_t - X_{t-1}$  once, or repeating this difference multiple times, a time series can be made stationary enough for ARIMA to be applied. The parameter "d" in ARIMA(p, d, q) represents the number of times the

differences are to be taken. The stationarity of the time series can be tested using the Dicky-Fuller test.

The orders  $p$  and  $q$  can be found by plotting the partial autocorrelation (PACF) and correlation functions respectively on the time series data. The lag point where the correlation values in the plot become significantly small can be taken as the order  $p$ , e.g. in the PACF plot if the value of the correlation is less than 5% at lag 5, then  $p$  can be taken as 4. Similarly,  $q$  can be found. We used the NumXL add-in in Excel which has the functions to find all these plots and to form the ARIMA model. ARIMA modelling can also be done in R with the ARIMA library.

### Neural networks

Neural networks is a very popular machine learning tool used for applications such as regression, classification, data processing, and robotics (Carbonneau et al., 2008). It consists of multiple layers of neurons connected by scalar weights and functions. It is a supervised learning model. The back propagation algorithm calculates the errors using an error function at the output and back propagates it, making changes in the edge weights accordingly. It iterates in this way to minimize the error and to train the model.

For time series prediction, there are no input attributes such as the market characteristics to help predict the market demand. Neural network would take the past values of demand as input and with it predict the demand using a feedback loop-like structure with delays. There are no specific assumptions in the neural networks other than the general assumption that the data on which it is trained and tested should both be similarly distributed. We use Matlab's Neural Network Toolbox for this. As the available dataset is very small (92 samples) for training a neural network, the error in prediction would be large. As such, we interpolated the available dataset to obtain a larger dataset. The obtained dataset is then sub-divided into the training and test samples.

Two other parameters to vary are the number of delays (inputs), and the number of neurons. We want to optimize these parameters to yield the best results. For a good model fit, there should be no autocorrelation in the prediction errors, and the correlation between the errors and inputs should also be very small, otherwise we need to improve the model. Neural networks are considered to be a universal function approximator and can be used on any data without any data specifications, unlike most other parametric methods. This model is more noise tolerant and capable of learning on complex data, making it suitable for forecasting wild demand fluctuations (Cao and Tay, 2003).

### Adaptive neuro fuzzy inference system (ANFIS) (Efendigil et al. (2008) for details)

ANFIS is a type of artificial neural network which combines fuzzy logic and neural network. It has the advantages of both fuzzy logic and neural network. The fuzzy logic inference part after learning can approximate the non-linear functions. From Figure 1, the structure of ANFIS can be seen as a 5-layer neural network. Multiple inputs are given to layer 1 which has linguistic labels or membership functions (such as "small" or "large") at each node which generates an output value between 0 and 1, according to the extent the input satisfies that quantifier. Layer 2 outputs the product of the incoming node, representing the firing power of each rule. Layer 3 does the normalization of the firing strengths. Layer 4 contains the adaptive nodes and its function is:  $\text{Out} = \bar{w}_i(p_i x + q_i y + r_i)$ . Here  $w_i$  are the normalized firing strengths, and  $p, q, r$  are the parameters. Layer 5 sums all the incoming values to give the output. The training algorithm modifies Layers 1 to 4 to match the training data and generates the model (Efendigil et al., 2008).

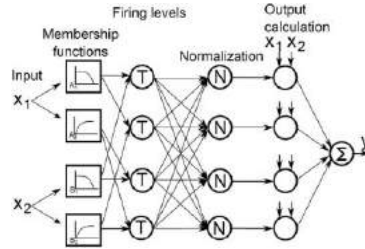


Fig. 1: Adaptive neuro fuzzy inference model

Like neural networks, there are no specific assumptions in the ANFIS model other than that the data on which it is trained and tested should both be similarly distributed. We implemented the ANFIS model in Matlab. We used the interpolated dataset to ensure a larger training sample.

**SVM** (see SVM (2017) for more details)

SVM is a machine learning approach for classification and regression analysis, and it uses kernel functions to find the deviations of the data points. SVM transforms the input  $x_i$  in an  $m$  dimensional feature space using non-linear functions, and then a linear model is created in the feature space. It then performs a linear regression in multidimensional feature space using a loss function. The optimization problem is formulated as

$$\begin{aligned} \text{Min } & \frac{1}{2} \|w\|^2 + C \sum_{i=1}^n (\varepsilon_i + \varepsilon_i^*) \\ \text{s.t. } & y_i - f(x_i, w) \leq \epsilon + \varepsilon_i^*, \\ & f(x_i, w) - y_i \leq \epsilon + \varepsilon_i, \\ & \varepsilon_i, \varepsilon_i^* \geq 0, i = 1, 2, \dots, n \end{aligned}$$

where  $\varepsilon_i, \varepsilon_i^*$  are the terms which measure the deviation of the training sample.

The term  $\frac{1}{2} \|w\|^2$  controls the complexity of the regression and the parameter  $C$  controls the weight of the error term. If  $C$  is large, then the focus is to minimize the error term than complexity. The parameter  $\epsilon$  controls the  $\epsilon$  - insensitive zone used to fit the training data. It affects the number of support vectors used to generate the regression function. The larger the value of  $\epsilon$ , the fewer the number of support vectors and the regression would yield a flatter estimate. Thus, we need to select  $\epsilon$  and  $C$  well (Cao and Tay, 2003).

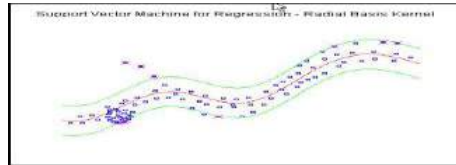


Fig. 2: SVM regression (source: kernelsvm.tripod.com, Fig. 6)

Note: the green lines are the  $\epsilon$  boundaries, the blue dots are the data instances

We can train a Gaussian kernel SVM for our data using the SVM module in R, as suggested in Figure 2. We can vary  $\epsilon$  and  $C$  to find the combination which gives the best results. A disadvantage with SVM is that the training time increases quadratically to cubic with sample size. As such, the training of large samples will require more computational effort (Cao and Tay, 2003). Again, there are no specific assumptions in SVM, other than that the data on which it is trained and tested should both be similarly distributed.

### 3. Results

#### Correlation analysis

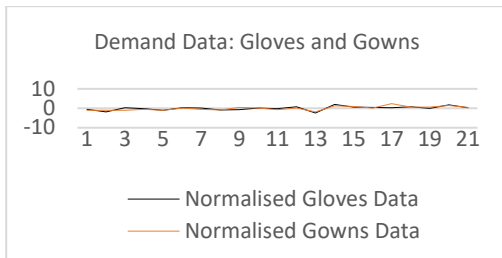


Fig. 3: Normalized total monthly demand of gloves and gowns

Product	Correlation
Total Gloves and Gowns	0.73
Surgical Masks and Gowns	0.79
Gloves - Nitrile Hands & Dermagrip	-0.94
Gloves -Latex & GL Inter Go	-0.81
Syringes and Needles	0.04

Table 1: Demand correlation of products

From Table 1, we can find products which are highly correlated or negatively correlated. For instance, if the demand of gowns is increasing, then we can expect the demand for gloves to do likewise, as exemplified in Figure 3. The reason for this correlation is the highly dependent demand nature of the products particularly in the operating theatres. However, Table 1 also suggests no correlation between the syringes and needles. The information on the correlation of the demands of the products is useful in maintaining the future stock levels. Through this simple correlation analysis, a supply chain planner can better plan a combined transportation of two highly correlated products, optimally using the truck space in vessels and subsequently reduce the cost through better consolidation.

#### ARIMA

We interpolated the data points to increase the size of the dataset from 92 to 1,471. The time series is made stationary by taking the difference of the consecutive demand points. After training, the ARIMA model with 1,471 samples, made predictions on the next 200 samples. From Figure 4 on ARIMA(3,1,8), the forecast values are about the mean and the model generates a region in which the values lie within a confidence level. Future values lie in the dark grey region with 70% confidence and in the light grey region with 95% confidence. As we make predictions for a farther time point, the predicted value approached the mean quickly and the error region also widened for the confidence levels as the accuracy of prediction weakens at farther time points. Thus, ARIMA cannot provide a good forecast when demand is chaotic, choosing a region for the value instead. Thus, ARIMA is not ideal for making long-term predictions when the dataset is small.

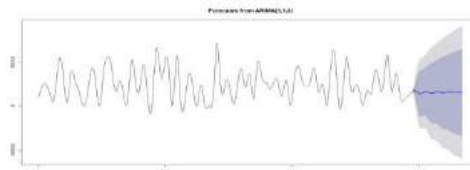


Fig. 4: ARIMA(3,1,8) prediction

Next, we tested the ARIMA model by forecasting only the next demand point each time for 500 samples from the interpolated dataset (see Figure 5). We find that forecasting this way yields a better forecast as shown in Figure 6.

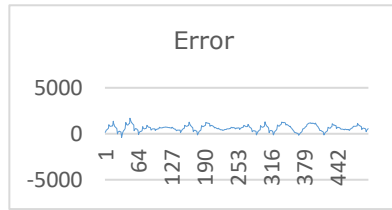


Fig. 5: Error in forecasting (500 samples)

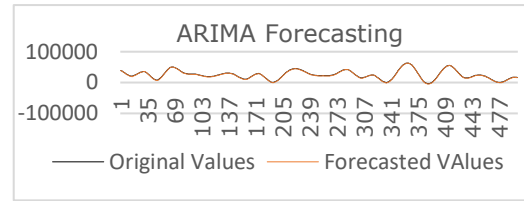


Fig. 6: Original and forecast values

Root mean squared error/Mean (RMSE/M) for ARIMA = 0.027894.

## Neural networks

A large dataset is needed to train the neural network. If the demand pattern is chaotic, the number of samples required to train the model will need to be much more. We interpolated the dataset provided from 92 to 1,471, so as to increase the number of samples and implemented the neural network using the Neural Network Toolbox. Figure 7 shows the results and the error plots respectively.

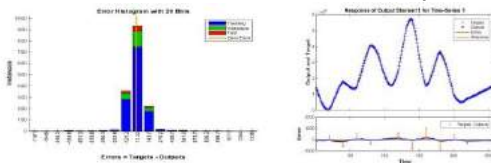


Fig. 7: Output of neural network trained on interpolated dataset a) Histogram of errors b) Predicted curve and original values, Error plot (test case – 260 samples)

As the number of samples increases, the MSE decreases (see Figure 8). However, the samples cannot be increased indefinitely because of model over-fitting and the time taken to train the model also increases. To get a better sense of the error relative to the scale of the data points, a better measure would be the RMSE divided by mean of the samples (RMSE/Mean), as shown in Table 2. The results also vary with the number of neurons in each layer and the delay in the neural network. The best results is when the number of neurons is 10, and the delay is 2.

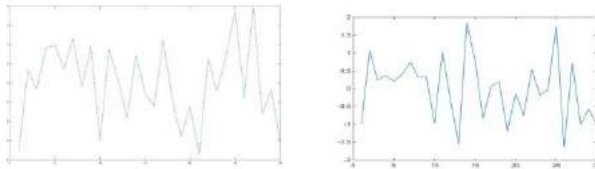


Fig. 8: Prediction error for model trained on: a) 7,680 samples b) 14,160 samples

Table 2: MSE\*, RMSE/M for test cases with different sample sizes

Interpolation Factor	Sample Size	MSE*(Test)	RMSE/M(Test)
128	11776	4.1121	8.30E-05
150	13800	3.1484	7.30E-05
236	21712	0.7784	3.60E-05

## ANFIS model

We divided the interpolated samples in a 60:32 ratio for the training and test samples. We implemented the model in Matlab. The training of ANFIS took less time compared to the other models. Increasing the number of training samples lowered the error but with further increase, the test error also increased indicating model overfitting as shown by Figure 9. The best results were obtained when trained on 9,600 samples (interpolation factor = 160).

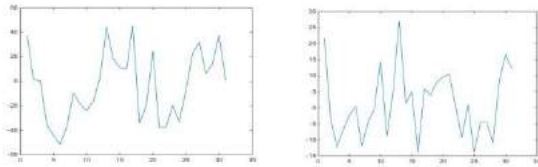


Fig. 9: Forecast error (31 test samples) for models trained on a) 5760 samples, interpolation factor 96 b) 9600 samples, interpolation factor 160

Table 3: MSE\*, RMSE/M for trained and test cases with different samples

Interp. factor	No. samples	MSE*(Train)	RMSE/M(Train)	MSE*(Test)	RMSE/M(Test)
96	8832	8.67E+04	0.0119	551.6	0.0012
128	11776	4.94E+04	0.009	785.5	0.0009
160	14720	3.00E+04	0.007	108	0.0004
256	23552	1.08E+04	0.004	4.40E+08	0.864

## SVM

We used the Gaussian kernel SVM and again trained it on different samples. The size of the dataset is increased by interpolation.  $x(t), x(t-6), x(t-12), x(t-18)$  are given as inputs for  $x(t+6)$  as the output. The parameters of the SVM model need to be set according to the curve to fit else the results would not be a good match. Other than epsilon and C, gamma  $\gamma$  is the free parameter of the Gaussian kernel which needs to be set (Cao and Tay, 2003). The combination of these 3 parameters and samples are to get the best results. The RMSE/Mean obtained with SVM trained on 1000 samples and tested on 500 samples is 0.313 and this is very large compared to the other methods. We have used the e1071 library for SVM in R.

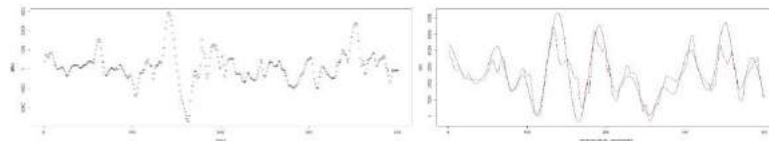


Fig. 10: Results for SVM model trained on 600 samples,  $\epsilon=0.002$ ,  $c=2^{20}$ ,  $\gamma=8$ , interp. factor 16 a) error plot b) forecast results

## 5. Conclusion

We have addressed the problem of analyzing poorly or ill-formed data generated from supply chain operations and showed how the existing analytics techniques can be efficiently applied on small datasets rather than merely seeking large datasets to work on. This moves the paradigm away from the need to rely on large datasets to improve supply chain performance, and hence reduce the degree of data pollution. Further, we have highlighted how data can be cleansed before performing any analysis to remove any inconsistencies and errors. The usual caveat applies: the dataset needs to be modified to suit the assumptions and requirements of the method used. We investigated four methods (statistical and machine learning) to forecast the demand for an actual firm. Neural networks yield the best results, in terms of errors, with no assumptions on the dataset unlike ARIMA which requires a stationary time series. However, neural network and ANFIS require large data samples for training. We have shown how to overcome this limitation; we interpolated a small dataset (92 samples) by a factor of 160 to train the models. While ARIMA does not require such a large number of samples, the results by the machine learning approaches are far better than the statistical approach. The time taken by machine learning methods is relatively more than ARIMA. As SVM gave poor prediction results, it is not suitable for forecasting a chaotic time series. The libraries and in-depth documentation of these methods are available in Matlab, R, and Excel which can be easily used to customize and implement the techniques mentioned in this paper to be used by supply chain planners who are constantly inundated with poorly formed data.



# **DEVELOPING A FRAMEWORK TOWARDS IMPROVING LOGISTICS PERFORMANCE IN MANUFACTURING COMPANIES**

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## **Abstract**

### **Purpose of this paper**

This paper contemplates in showing the inherent link between logistics performance and organisational performance. The development of key performance metrics having a direct impact on logistics performance in manufacturing companies are probed. The end result of this research is the development of a framework for optimising logistics performance which will help companies in assessing their logistics function and identify loop holes in their systems.

### **Design/methodology/approach:**

This study uses both exploratory and descriptive research in analysing current practices in the manufacturing sector with regards to logistics so as to develop the required performance measurements that form the basis of the developed framework. This paper employs an extensive literature to enquire on existing models but also at the different techniques to develop the key metrics. A questionnaire was developed to carry out a study on the current/best practices in the sector. Once the framework was built, it was then tested and validated through expert opinions.

### **Findings:**

While surveying companies to assess their current practices in logistics performance management, it was found that the main elements to focus on was Quality, Costs, Productivity and Time. From the developed framework, it was deducted that for any organisation together with the 5 logistics components as per Isermann (1994): Order Processing, Warehousing & Inventory, Transport, IT and Additional Services, should be considered as complementary. This framework provides decision makers with a well-balanced picture of the logistics performance.

### **Value:**

In logistics literature, more attention has been placed on individual measures rather than on system measures. This research work not only comes up with a framework for achieving optimum logistics performance but also provides benchmark values to stakeholders of the industry to know where they stand. In addition, the key performance metrics developed in this study are very specific and relevant to the manufacturing sector.

### **Practical implications**

The resulting framework is based on Logistics performance and in no way guarantees overall success without the implication of stakeholders of the industry. In order to achieve optimum performance, it must be clear to organisations that they to use a more holistic approach in every aspect of their core business practices. Logistics encompasses a set of focus activities of the businesses leading towards high performance.

## **INTRODUCTION**

With the advent of globalization, companies now face increasing competitive pressure and the need to maintain and/or improve profitability has become key to survival. Management needs to constantly innovate to gain competitive advantage over rivals. While the concept of competitive advantage in its simplest form deals

with how companies manage to outdo rivals to gain greater market share or profits, the main complications lie in the setting up the right strategies to do so.

The changing business environment has given stimulus to managers to develop new perspectives of various managerial functions that include marketing, design, production, finance, accounting and human resources. The end result would arguably be to satisfy customers but assuming that customer satisfaction is a derived attainment and occurs only after organizations are efficient to meet customer demands, it can be established that one main way to achieve competitive edge in the market is by being efficient during the process of satisfying orders. Internal efficiency is a vast subject and applies to the whole of the supply chain as it encompasses all of those activities associated with moving goods from the raw-materials stage through to the end user. This new managerial perspective however require new tools in terms of suitable performance measures and metrics so that the resources available can be judiciously utilized for producing quality goods and consecutively enhance the organisational competitiveness.

Companies can further gain competitive advantage by performing such strategically important activities more efficiently than their competitors (Christopher, 1999). Since the business environments have changed over the years, it has now become essential to determine whether the existing performance measures and metrics can be used or see if a new set of performance measures in addition to the existing ones are required. This needs to be applied to today's enterprises which are portrayed by supply chain and physically distributed global operations. An attempt has been made in this paper to determine the most appropriate performance measures for supply chain and most specifically logistics.

Since the 2000's the concept of logistics has greatly evolved and touted as one key element in the supply chain to help gain competitive edge. Strong management focus on Logistics has been growing steadily over the years. In the 1990's logistics and supply chain management was already identified as an important source of competitive advantage (Olavarrieta & Ellinger, 1997; Day, 1994). This was later confirmed by Stock & Lambert (2001) who recognised the major reasons for growing logistics importance recognition which are attributed to:

- Recognition of the role of logistics in a company's customer service programme
- Profit leverage resulting from increased logistics efficiency
- Development of the systems approach and total cost analysis concept
- Erosion of companies' profits because of their failure to examine functional areas where cost savings might be realized
- Customer requirements for value-added services continuing to drive costs up

## **LINKING LOGISTICS & ORGANIZATIONAL PERFORMANCE**

### **Organizational Performance (OP)**

Organizations play important roles in determining the economic, social and political progress. OP in its simplest day to day definition refers to how well an organization is doing to reach its vision, mission, and goals. Assessing OP is a vital aspect of strategic management. Executives must know how well their organizations are performing to figure out what strategic changes, if any, to make. Performance is a very complex concept, however, and a lot of attention needs to be paid to how it is assessed. Lebas & Euske (2006) after Kaplan & Norton (1996), tried to shed light on the term by declaring that Performance is a set of financial and nonfinancial indicators which offer information on the degree of achievement of objectives.

Logistics performance can be defined as "effectiveness and efficiency in performing logistics activities" (Mentzer & Konrad, 1992)." Bowersox et al.(1996) first demonstrated that logistics performance comprised of a methodology for analyzing resources of a logistic system and that the main aims were to control and monitor logistic operations. Though this preliminary work marked a big step for logistics performance management, according to Robb et al.(2008) since Logistics deal with physical, informational and cash flow management, and it is a huge business success determinant, the practices in terms of performance analysis are still under-studied in literature.

The work of Larson et al. (2007) is one significant study that shows the relationship between logistic and OP. In the research, managers and business leaders were asked about the perception of logistic performance on business success and they all concluded that better performance in customer service, better inventory and optimization costs were essential for businesses to be profitable. Since the new globalized business world is putting ever more pressure on logistics to contribute to OP, various authors have evaluated the link and interdependence. Green Jr et al.(2008) addressed the relationship in a large number of companies in the US and the study concluded that it has a direct positive link since the speed of delivery& flexibility of delivery impact the marketing function through sales and profitability. Roth et al.(2008) examined the performance of leading global companies and concluded that information technology and logistics contribute to more sales and profits.

Measuring logistic performance is thus key to boosting OP. Bhagwat and Sharma (2007) claimed that analysis of logistic performance is one of the main challenges facing today's companies. Moreover, Schramm-Klein and Morschett(2006) highlighted that analysis of logistic performance is a strong trend and it involves monitoring and planning to establish links between the results of indicators and the firm, determining how well companies achieve strategic objectives as part of their definition and competitive orientation (Gunasekaran and Kobu, 2007).

Fugate et al. (2010) analyzed the relationship between logistics performance and organizational performance, stating that logistics performance is multidimensional and is a function of the resources used in logistics, according to outlined objectives and outcomes against competitors. Thus it was summarized that all logistic activities should be evaluated. Fugate et al. (2010) also claimed that logistics can "create value through efficiency, effectiveness, and differentiation. According to the study, efficiency concerns resources use in the logistic system, effectiveness is the extent to which targets are met and differentiation is defined as the ability to induce customer loyalty against competitors. Therefore, Fugate et al (2010) in analyzing the interrelationships of logistic between elements of logistic performance came up with the below model which aimed at showing (1) the central level where the authors seek to obtain the final result of the investigation & (2) examining the variables of logistic performance. The model has been tested in various companies.

Toyli et al.(2008) analyzed logistics performance in Small and Medium Enterprises in Finland and the study primarily based on the relationship between logistic performance and financial performance. They concluded that logistic performance is linked to efficient and consistent operations and involve cost efficiency and high productivity. According to the researchers, Logistic performance is a multidimensional variable that include cost efficiency, service quality and operational performance metrics.

Toyli et al. (2008) thus defined Logistic Performance as having 3 dimensions:  
(1) Service Level, i.e service quality to clients, (2) operational metrics, examples are time, inventory levels etc. & (3) Logistic Costs.

Toyli et al. (2208) proposed a framework for performance analysis that aims at facilitating performance research which incorporated the following elements:

- (1) Elements of Logistics profile that includes evaluation and improvement of logistic performance
- (2) Logistic Performance which includes Theories of Logistic Cost efficiency, Service Quality & Time
- (3) Financial Performance including profitability, productivity and growth

These models however have attracted criticism. Some authors have analysed the concepts of business objectives and efficiency & effectiveness and concluded that while setting a business goal, leaders should opt for one dimension only since progress in one dimension might mean steps backwards for another. Fugate et al (2010) refute the criticisms by arguing that firms choose to combine elements of efficiency and effectiveness in decision making achieve better success.

## **FRAMEWORK DEVELOPMENT**

### **Designing the Right Performance metrics**

The Net Present Value and Return on Investment are too financially-driven. Various authors have suggested the need to cover both financial and non-financial factors for decision-making. The Balanced Scorecard brings the needed change by arranging performance management in different homogenous categories. Critical Success Factors are qualitative and less applicable to the study. The SCOR model remains a robust logistics benchmarking tool but is however unsuited for analysing performance of a single functional area. The best suited and hence chosen method of performance measurement is therefore Key Performance Indicators (KPI) for this paper. In fact, all of the above techniques, are KPI-driven. The KPI method provides clear direction to management and allows easy performance tracking. Moreover, it also allows to manage for effectively and objectively. However, the method suffers from the drawbacks of needing unambiguous design and being costly and time consuming to indulge in.

KPIs are quantifiable measurements that depict the critical success factors of an area/business. A metric is a standard definition of any measurable quantity, and a performance metric is a standard definition of a measurable quantity that indicates some aspect of performance. Performance metrics need certain characteristics to be valuable and practical. A performance metric should:

- Be measurable (or able to be determined from other measurements).
- Have a clear definition, including boundaries of the measurements.
- Indicate progress toward a performance goal.
- Answer specific questions about the performance.

KPIs are quantifiable metrics which are usually defined and measured over a period of time or during a specific time interval.

### **Identifying the right environment**

#### **The Logistics System**

Figure 1 depicts a holistic view of a logistics system. It comprises of:

1. The Core Elements which involve Order Processing, Storage & Transport
2. Logistics Information Management
3. Additional Services

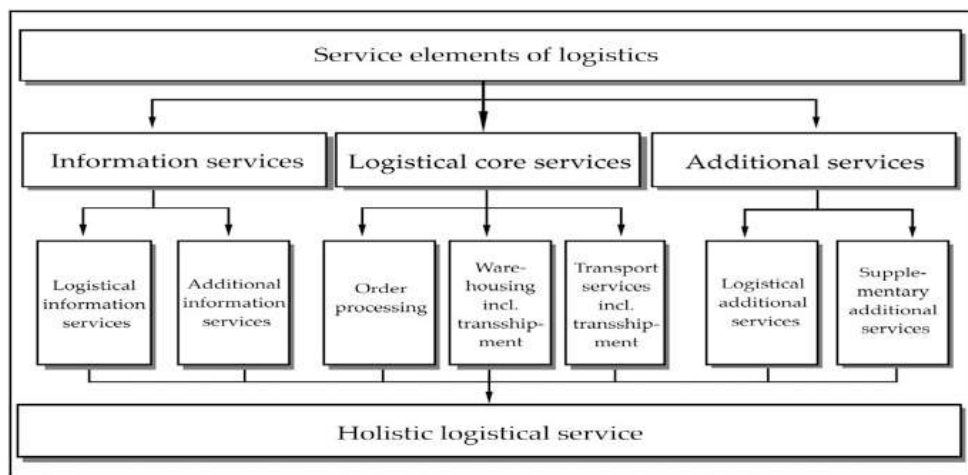


Figure 1: System of logistical services (Cf. Isermann 1994, p. 25)

It is common belief that what gets measured gets improved. However, the most important aspect remains in detailing what needs be measured as since we measure the wrong things, we may not achieve objectives. As propounded by various authors in literature, indicators should be both financial and non-financial and need to cover all areas of business functions. The same principle applies to the supply chain function and while focusing on a single element might help improve that particular sub-function, the total performance of the supply chain might not improve satisfactorily. For this need, Edward Frazelle's (2002) model has been adapted to this study. The Model proposes 4 areas of KPI namely: **Quality, Time, Financial, and Productivity**.

Isermann (1994) and Frazelle's (2002) models of logistics system and KPI categorization represented very robust and unanimously accepted ones in the Logistics field. A questionnaire study was conducted amongst the major players in the Mauritian Logistics field and different problem areas were studied in firms' logistics functioning. Studied organisations had their system analysed to determine blockages and reasons thereof. Based on the findings, comparisons were thus made and parallels were drawn as to what caused major bottlenecks. KPIs were lastly developed as depicted in Figure 2.

	QUALITY		COSTS		PRODUCTIVITY		TIME	
	KPI	Measurement	KPI	Measurement	KPI	Measurement	KPI	Measurement
Order Processing	Order Entry Accuracy	(Total Error Free Data Entries )/Total number of Orders	Order Processing Costs	Total Order Processing Costs/ Sales Revenue	Order Processing Per Worker	Total Orders Processed Correctly/ Number of Workers	Order Entry Time	Customer Order Placement-Time of Order Entry
	Documentaion Accuracy	(Total Orders Documented Correctly/Total Orders Processed)					Documentation Cycle Time	Time Final Order Shipped-Time Final Documentation Complete
Warehousing & Inventory	Receiving Accuracy	Total Correct Reception/ Total No of Receptions	Storage Costs	Current Occupied Locations/ Total Warehousing Costs	Capacity Utilization	Occupied Locations/Total Capacity	Order Preparation Cycle time	Time Order Placed in System- Time Order Picked
	Handling Accuracy	Total Orders Picked & Prepared Correctly/ Total Order Pickings	Inventory	Total Inventory Costs/Sales Revenue	Labor	Stock Movements/ No of Workers		
	Inventory Fulfillment	Total Requests Satisfied/ Total Order Requests			Machine	Stock Movements/ No of Machines		
Transport	Transport Accuracy	Total Number of Correct Deliveries/ Total No of Deliveries	Delivery Cost	Costs of Volume of Goods Delivered/ Sales Revenue	Labor	Qty of Goods Delivered/ Operating Hours	Time	Number of Late Deliveries/ Total No of Deliveries
	Delivery Accuracy	Total No of Deliveries without damage/ Total No of Deliveries			Vehicle	Distance Run/ Fuel Consumed		
IT Services	Ability To Generate Accurate Data when required		IT Costs	IT Costs/Sales Revenue				
Additional Services	Special Request Fulfilment	No of Special Order Requests met/ Total No of Special Order Requests						
Summary of KPIs for Logistics Service Elements								

Figure 2: Key Performance Indicators

A Logistics Performance Framework was developed as depicted in figure 3.

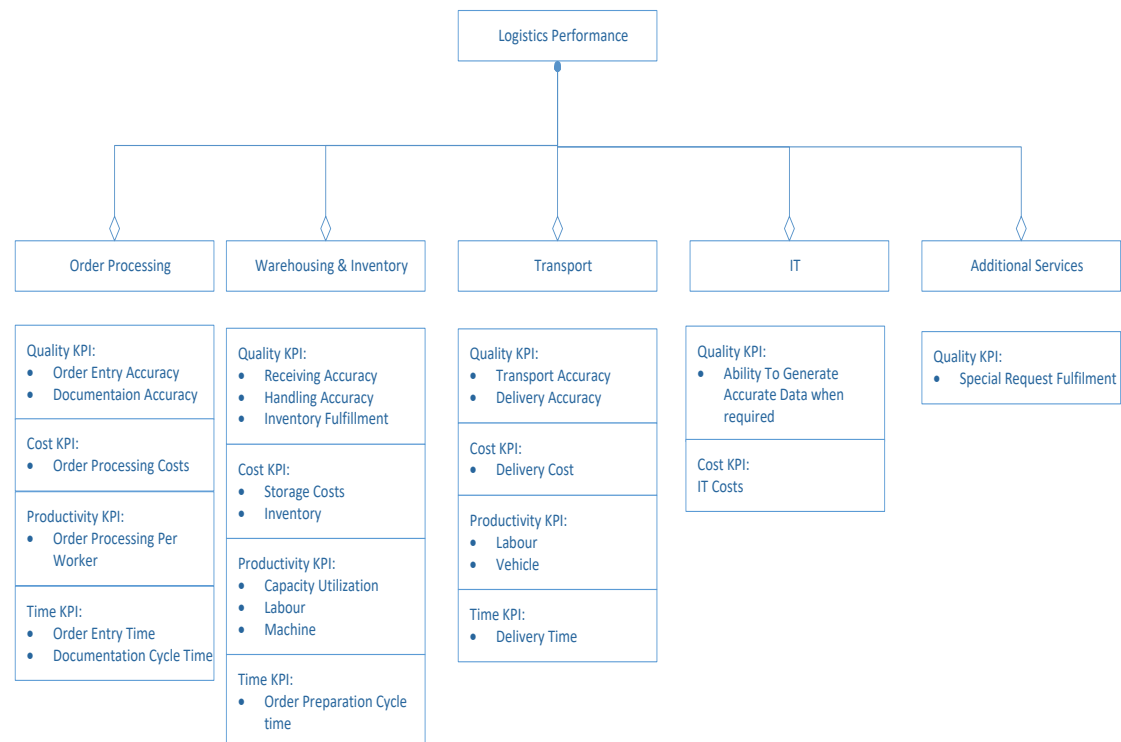


Figure 3: Framework for Logistics Performance

From figure 3, it is therefore deduced that for any organisations looking forward to achieve good logistic performance, it is of utmost importance to them to focus on the five components that form part of the proposed framework: Order Processing, Warehousing & Inventory, Transport, Information Technology and Additional Services. Each component is assessed in terms of the quality level, cost, productivity and time. If manufacturing companies in Mauritius want to survive global competition and be among the best, it is imperative that the KPIs are above averaged.

Since the KPIs developed in literature for logistics are few, it would be difficult for them to benchmark themselves. However it is proposed that these indicators are included in the yearly performance report. Hence they can use the KPIs as references and compare their performance over successive years.

## CONCLUSION

Performance Measurement and Metrics are essential for effectively managing supply chain and logistics operations. The primary aim of this study was to develop a framework to measure logistics performance. The methodology used mainly figured literature reviews which, coupled with the questionnaire, aimed at developing performance measurement metrics for continuous improvement. To some extent, it was possible to gather information from various sources. However, due to time and resources constraints, parts of the study remained incomplete, especially testing. One of the main criticisms during the expert opinion study was the lack of real-time testing. In order to understand the importance of nonfinancial measures and intangibles, a list of KPIs in supply chain and logistics environment was developed. Though some attempts were made to test KPIs, generally organizations refused to provide required data for analysis, judged to be too confidential. In addition, benchmark setting for all KPIs were not available during literature review, thus attempts were made to provide benchmark values for most dominant KPI components of the framework.

This study thus depicts the forming of a framework, with relative testing and benchmark. It cannot be considered as final since a further continuity to ensure relevance shall include a more in-depth and rigorous testing in real-life situations and more analyses to determine benchmarks in the local context. The study bases itself on Logistics performance and in no way guarantees overall success. It paves the way for improvement in only one part of the whole process of customer satisfaction. It becomes clear that businesses now need to be efficient in every aspect, right from top management strategies down to floor/layman details. The holistic approach mantra has to be the core of business practices.

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# THE LOGISTICS PROVIDERS' CONTRIBUTION IN THE CONTRACTORS' CHAINS INTEGRATION IN MOROCCO

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**Abstract**---The large movement of outsourcing and focusing on the key-skills has conducted to the creation of the new profession of "logistic service providers", which are positioned as real interfaces pilots and constitute a radical innovation of the managerial, strategic and operational plan. Being based on a scientific analysis, this works aims to identify the factors that have an impact on the LSP contribution, and to define, later on, the characteristics required by the logistic service providers, to highly contribute to the logistics chains and to perform their role of integrators.

Through the case of Logistics providers that are operating in Morocco, we will bring clarifications that foster the new characterization techniques of LSP, which are founded, more and more, on their ability to control and coordinate various integration layers, (flows, processes and activities, Information system and actors), rather than on traditional elements of costs, quality and delays.

*Key words:* Contribution, Logistic Service Providers, Supply chain, Integrated logistics

## INTRODUCTION

Logistics are seen, nowadays, as a major element to affirm a sustainable competitive advantage, and becomes a truly strategic approach for companies that increasingly require resources. The refocusing of industrials on their core business promoted the logistics function outsourcing, thus contributing in the creation of the logistics service market.

This article aims to enlighten the real contribution of the LSP to the contractors' chains integration. The identification of gaps and of some explanatory factors could provide enlightenments promoting the development of new LSP characterization techniques, based on their ability to control and coordinate different integration layers (flows, process and activities, information systems, and actors) rather than the traditional elements of costs and delays.

In short, this will allow to indentify the factors that impact the LSP contribution, and to define, later on, the characteristics required by the logistic service providers, to perform their integrator role.

## 1. State of the art

### 1.1. The logistics service

There is no consensus in literature on the definition of a logistic service provider. Authors like [1] have shown the difficulty to agree on the contrasted definition of the logistics service and of its actors.

In literature, most of the contributions are focused on the outsourcing concept, without even returning explicitly to the meaning of "logistics" within this context. [2] define a "logistic service provider" as an external provider who assumes the complete logistic function of the firm, or a part of it". [3] join the same definition, adding that the provider should be able to assume a combination of at least two activities, in a coordinated or integrated way.

Thus, when it comes to logistics services, definitions that accentuate the different aspects of the outsourcing operations (service, nature and duration of the service...) overlap and show a chronological evolution of the logistics service performance and of the carriage execution, to more sophisticated services, included within a longer term perspective.

## **Theoretical foundations of the logistics service**

Starting from the fact that firms are based, in their decision to do business with an LSP, on factors such as: cost reduction, the company's network, resources owned by the PSL, as well as its expertise, we identify:

### ***The transaction cost theory***

This theory aims to evaluate the properties and the respective costs of the different ways to coordinate transactions. These transactions are characterized by three essential dimensions: asset specificities, uncertainty and frequency.

The aim is to define the governance structure which minimizes the transaction costs, depending on the frequency degree of transactions and of the specific assets degree, knowing that economic agents have a limited rationality.

### ***1.2.2. The Resource-Base View theory***

This theory draws its relevance from the fact that it allows the discovery of strategic assets for the company. It stipulates that the competitive position of the firm is determined by a set of resources and by their interactions. We will retain, at this level, the characteristics of resources and the technological characteristics.

### ***1.2.3. The inter-firm cooperation***

A dynamical approach, since the inter-firm alliances are considered as an alternative form of coordination. This theory leads us to take in account the partnership characteristics and the external environment as factors. We are interested, at this level, in three forms of inter-firm cooperation:

**Sub-contracting:** Outsourcing act by which a company imparts the making of tasks of its own commercial responsibility to an external partner [4].

**Partnership:** the partnership constitutes the first step of a cooperation relation that exceeds the logical authority of short term contracts, in order to leave room to more lasting relations [5].

**The network:** The inter-organizational network, which links companies or other forms of legal persons, has a form of governance that is stable and alternative to market-hierarchy dichotomy [6].

### ***1.2.4. The network theory***

The network approach counts three components: activities, actors and resources. According to [7], this holistic analysis seems suitable for assets that are highly developed, in which the role and importance of the logistics provider could be included. In fact, the network approach provides useful concepts to describe the real role of logistics providers in a network, and lends itself towards a thorough diagnosis of this contribution. In other words, this approach must provide an adapted reading grid, to insure a better understanding of the logistics providers' role in a supply chain context.

**Suggestion of a conceptual model of factors impacting the LSP contribution to the integration of contractors' chains.**

The suggested model is made of articulations of seven fundamental axes, which are the ***LSP profile, the characteristics of logistics resources, the technological characteristics, the relational characteristics, the characteristics of the provided service, the characteristics of the external environment, and the contribution level to integration***. Its underlying logic could be expressed as follows:

The development of all the previously mentioned characteristics, as well as the sophistication of a logistics system in the LSP, mainly explain the level of its contribution to the chain integration. This model has first emphasized that the contribution, highlighted by an LSP, depends on the characteristics block.

**Figure n°1 – Conceptual model of factors impacting the LSP contribution to the integration of contractors' chains.**

<b>LSP profile</b> <i>Number of years in practice</i> <i>Sales revenue</i> <i>Firm size</i> <i>Main services</i> <i>Added value services</i> <i>Nature of treated flows</i> <i>Number of clients</i> <i>Destinations</i>	<b>Characteristics of resources</b>  <i>Specialized staff resources</i> <i>Equipment resources</i> <i>Infrastructures resources</i> <i>Infrastructures area</i>	<b>Technological characteristics</b>  <i>Intensity of the ICT use</i> <i>Internal use for functions integration</i> <i>External use of relations with other LSP</i> <i>External use of relations with shippers</i> <i>External use for the integrated chains management</i>
<b>Contribution</b>		
<b>Characteristics of the service</b>  <i>Intermodal connection</i> <i>Service flexibility</i> <i>Service quality</i> <i>Geographical coverage rate</i> <i>Variety and frequency service</i> <i>Ability to resolve problems</i> <i>Ability to retain relations</i>	<b>Relational characteristics</b>  <i>Relation types</i> <i>Sub-contracting use</i> <i>Contracts duration</i> <i>Relations evolution</i>	<b>Characteristics the external environment</b>  <i>Membership sectors of clients</i> <i>Pressure of contractors</i> <i>Competitiveness</i> <i>Demand</i> <i>Stability degrees of the service's market</i> <i>Threat of opportunities</i>

### **Empirical study:**

To answer our problematic, we have conducted a study, through a questionnaire, with logistics service providers operating in Morocco, mainly located in Casablanca. More precisely, our target population counts logistics service providers who provide two or more activities. The targeted population is made of 54 logistics service providers. Our sample is, thus, a non probabilistic type; more precisely, it consists, in our case, in a convenience sample including a number of 37 providers (a 68% rate).

The data collection, through a questionnaire, was performed in two stages. In the first one, our questionnaire was administrated by e-mailing the logistics service providers. We have realized the administration of questionnaires with the sector's experts, in order to avoid the risks of misunderstanding and of mistakes arising from the auto-fill, which has allowed us to have open and enriching discussions.

The chosen methodology is a part of a hypothetical deductive approach of a quantitative nature. This approach allows collecting objective data, to test, validate the elaborated hypotheses, and to evaluate the typological model project towards a conclusive version.

### **2.1. Identification of factors affecting the logistics providers' contribution.**

Multi-nature statistical analyzes have been executed in order to identify the most relevant intangible characteristics that have a direct impact on the contribution of logistics providers. We have conducted, in a first step, a dependency test between the explanatory variables (characteristics) , and the variable to explain (contribution level), in order to estimate the strength of associating the dependent variable and each of the independent variables of our empirical model, through the **chi-squared** test.

In the second step, we have pushed our analysis to the most specific possible, by using the method of multiple correspondence analyses (MCA), as a complementary step. The MCA is here to complete the first step tests, since the results of it have reconfirmed the validated hypothesis, as well as other ones.

The result of the two steps allowed validating and identifying the following factors, which affect the logistics providers' contribution.

#### **2.1.1. LSP profile characteristics.**

The analyses conducted on this block have confirmed three factors:

**The number of years in practice:** Affect the contribution level, which means that the higher the number of years in practice is, the more the LSP records skills and expertise, to significantly contribute to the chain integration. 65% of the surveyed companies have been practicing for over 11 years.

**The nature of the treated flows:** This also affects the contribution level of LSP, since some flows are extremely complex and difficult to treat. Still, 97% of our respondents affirm their ability to manage multiple flows, namely: liquid bulk, building material, agricultural products, industrial goods and hazardous substances. This leads us to confirm that managing multiple flows is a prerequisite to any contribution of the contractors' chains.

**The destinations impact:** at this level, most of the respondents affirmed that the destinations' proportions required by shippers are the local and international, which means that the LSP should be able to meet the requirements of exporting firms, as well as the multinational exporting companies.

#### **2.1.2. Resources characteristics**

The conducted analysis on the four variables that constitute the Resources characteristics' block, depending on the "contribution level" variable, concluded that:

**The infrastructure number:** affects the contribution level. In other words, more the LSP has a significant infrastructure (platform, warehouse, MEAD, etc), the more important is its contribution. Therefore, we could consider the infrastructure number as a prerequisite that enables the LSP to enhance their contribution to the chains' integration. It's noteworthy that 54% of the sample has several infrastructure types all over the kingdom.

#### **2.1.3. LSP relational characteristics**

Our statistical analyses have allowed the validation and the identification of one single factor, among the suggested partnerships characteristics, namely:

##### **The use of sub-contracting**

This result proves the existence of a significant relation between the sub-contracting use variable and the contribution level. This seems logical to us, since 67% of the surveyed LSP use sub-contracting. To conclude, the LSP prefer maintaining long term coordination relationships rather than investing in the acquisition of new equipment.

#### **2.1.4. LSP service characteristics**

Through our analyses, we could validate and identify four factors among the suggested characteristics, mainly:

**The service flexibility:** which 89% of the surveyed LSP consider as "very important"

**The service quality:** 56% of our sample see the service quality as a "very important" characteristic.

**The ability to solve problems:** 49% of the LSP consider that this factor is "very important"

**The geographical coverage rate:** 54% consider that this factor is "important".

This shows that these characteristics are very important and essential prerequisites to highly contribute to the integration of the contractors' chains. Therefore, the LSP is required to meet these criteria to contribute to a very expanded integration of the contractors' chains.

#### **2.1.5. External environment characteristics:**

At this level, our analyses have allowed us to identify two factors, mainly:

**The contractors' pressure:** 70% of the surveyed companies said that they are increasingly subjected to the contractors' pressure.

**The opportunists' threat:** according to the survey, 67% of the LSP say that their market is "open to opportunists".

These two factors create a disrupting threat to the LSP in their relationship with contractors.

#### **2.1.6. Technological characteristics**

We notice that the external use factor for the chains' integrated management is validated, unlike those of internal use, specifying that 20% to 50% at least of the suggested technological tools provided in the questionnaire are used by the LSP. According to our survey, **54%** of our sample use ICT "with a medium average intensity" for external purposes related to the chains' integrated management.

#### **CONCLUSION**

In this article, we have aimed to locate the LSP, on a theoretical plan, depending on its network, partners, resources, activities and external environment, in order to explore the phenomenon of the logistics service, which is still poorly treated in academic literature. At this level, we believe that we have brought enlightenment on the LSP contribution in the logistics integration process in Morocco, through the identification and the analysis of factors that affect the LSP contribution to the chains' integration. We have, thus, identified factors impacting the LSP contribution, and defined, afterwards, the required characteristics by logistic service providers to highly contribute in the logistics chains and to achieve their integrator role.

The results of this work bring many allowances as well as limits. In addition, they reveal various perspectives of the future.

On the managerial scheme, they could help managers of industrial and commercial companies to a better choice of the LSP, as partners that could contribute to the integration of their chains and to the value creation. In addition, national and international firms could get more knowledge on the reality regarding the aspects of the LSP operating in Morocco.

This research could also help the LSP to make auto-evaluations, through the suggested intangible factors grid. The focus on these factors will allow the LSP to improve its offer and its behavior towards the different chain actors, in order to fit its external environment. This will promote the professionalization of logistics activities, as well as the development of the LSP as a key actor to the competitiveness and to the value creation for industrial and commercial firms.

Finally, the results of this work could become sources to help the decision of public authorities, namely the Ministry of Equipment, transport and logistics, the Moroccan Agency for logistics development, as well as the Moroccan observatory of logistics competitiveness. Likewise, they would help conceive and establish a classification and qualification system of the integrated logistics providers (labeling system), in order to develop logistics actors that are integrated, effective and able to provide reliable services that meet the requirements of national and international contractors.

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